The
# ENGINEERS' DIGEST

REVIEW OF WORLD ENGINEERING PROGRESS

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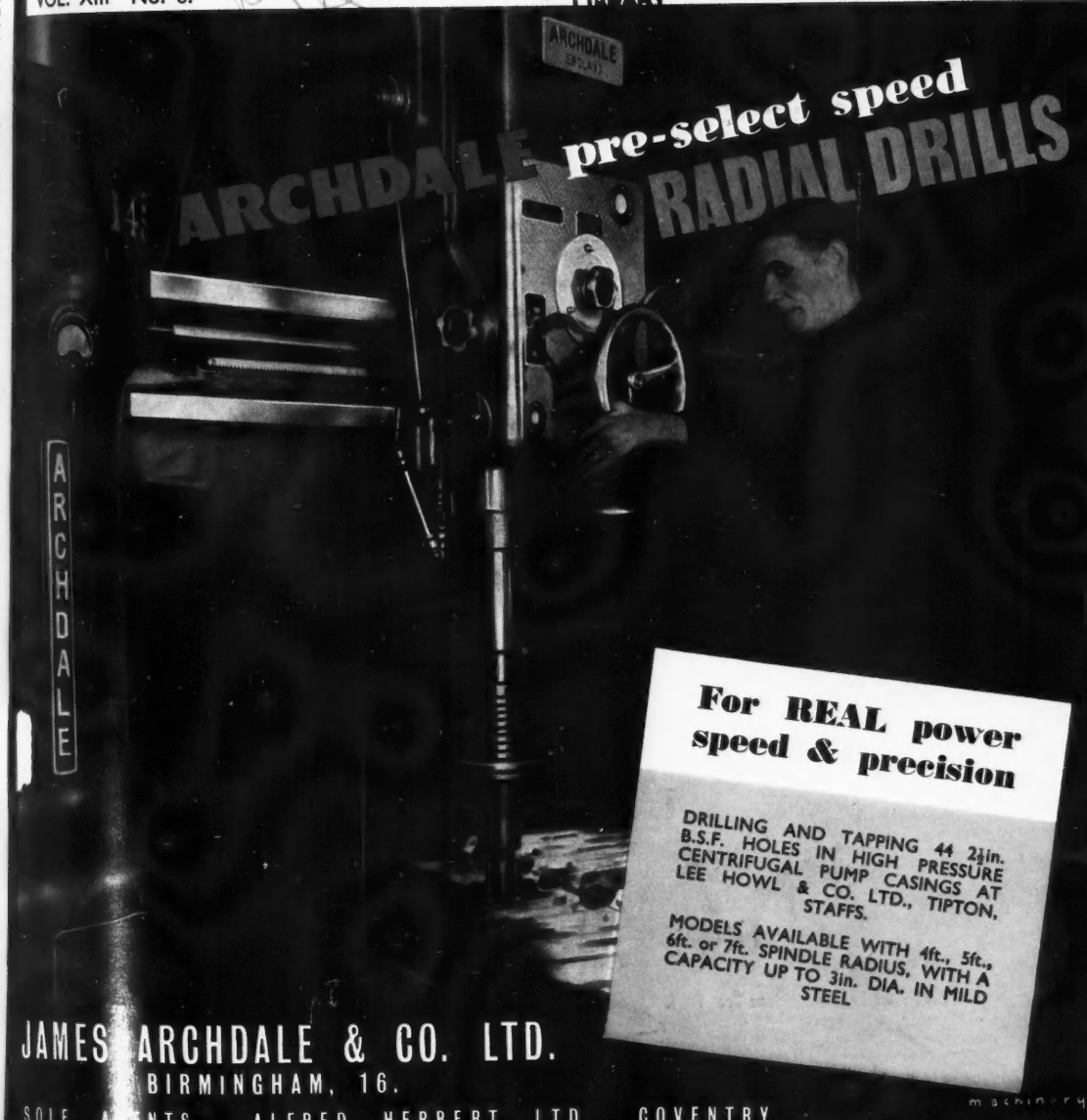
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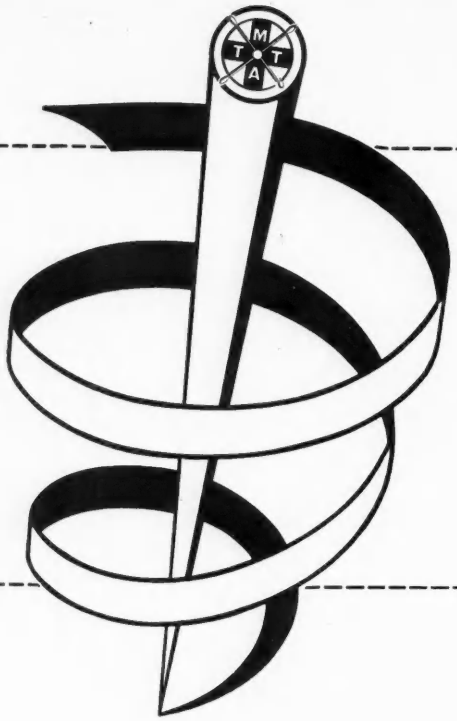


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# THE BLUE PAGES

## A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

### ● *PLASTIC MOULDS FOR PLASTICS*

According to a recent report, inexpensive casting moulds made from vinyl plastic are now being used by a firm of plastic manufacturers to produce various phenolic and polyester parts. These vinyl plastisol moulds are used in cases where only limited quantities of parts are required to be made and the initial expense in making elaborate metal moulds would not be justified. Also, if lead moulds are employed, the manufacturer is limited in certain design aspects because the draw has to be only in one direction. In the case of a plastic mould, however, the draw can be in several directions. From actual operating experience it has been found that approximately fifty phenolic parts can be made in a plastic mould before it must be discarded, and from ten to fifty polyester parts can be cast before breakdown of the mould occurs. To make a piece, liquid phenolic casting material is poured into the vinyl moulds which are then put into ovens. Fusion takes place at a temperature of 150 to 180° F. Polyester materials fuse at room temperature in one to six hours, depending upon the size and shape of the mould. In making a vinyl plastisol mould, a positive pattern fashioned from metal is placed in a container and the plastisol is poured so that it completely covers the pattern. This is then put into an oven and cured. After cooling, the surplus mould material is cleaned from the underside of the pattern. It is claimed that no expensive equipment is needed for mixing the ingredients.

### ● *OPTICAL SENSING IN CONTOUR MILLING*

A knee-type contour-copy milling machine with an optical sensing system has been developed to produce accurate parts at high production rates. The optical type of pick-up provides automatic control of copy feed rates and offers the advantage of increased accuracy by anticipating changes in the pattern contour. In addition, the system allows the use of paper patterns which can be easily prepared and stored—a traditional problem in shops where large numbers of patterns are required in short-run operations. In the new machine, when the pattern masks the light source, which is a zirconium arc light, the light signal is converted into an electric signal by means of a direct current amplifier circuit containing a photo-electric cell. Periodic light communication around the pattern is permitted between a spinning shutter and the photocell, and this is changed into a copy signal voltage pulse by the d.c. amplifier. The translator section of the electronic system serves to produce two polarized d.c. signal voltages. Owing to the nature of the sensing process, the workpiece produced is not a replica of the pattern, but the machine makes a male workpiece from a female pattern and a female workpiece from a male pattern. The details of the electronic system are of necessity highly complex, and there is no doubt that servicing of a machine of this type will best be carried out by highly trained electronic personnel. The pattern table of the machine can be removed from the work-table so that the new machine is also suitable for standard milling operations.

### ● *NEW METHOD OF X-RAY ANALYSIS*

Conventional X-ray diffraction equipment employs cameras and films for recording the intensity and angular relationship of the X-ray beam picked up from the specimen. As a matter of fact, for certain types of work, camera and film methods are still the best solution to the problem today. In many cases, however, the Geiger counter spectrometer provides accurate X-ray diffraction data in a much faster and less laborious manner, and this makes the instrument extremely useful for production control. In fluorescence analysis the primary X-ray beam is directed upon a stationary specimen, and the fluorescent radiation coming from the specimen is passed to a rock-salt crystal which acts as a diffraction grating. By dispersing the various wavelengths sufficiently widely, it is then possible individually to detect each wavelength by means of the Geiger tube and to measure the intensity of radiation. Fluorescence analysis makes it possible to examine specimens of various kinds and shapes. When dealing with a liquid or solution, the material is placed in an open-faced holder under a thin transparent membrane cover. Powdered material is placed in the open-faced holder and the surface is pressed flat. Metal specimens are cut to about one inch square by $\frac{1}{16}$ to $\frac{1}{4}$ in. thick to provide optimum thickness, although foils or evaporated films can be placed in the specimen holder. Irregularly shaped specimens, in which cutting or deforming is impractical, can be placed in the specimen holder in such a position that irradiation of a face can be accomplished.

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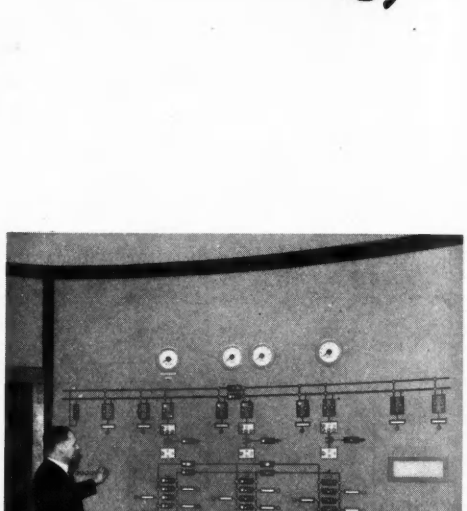

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### ● *NEW ALUMINIUM ETCHING BATH*

A new caustic etching compound for treating aluminium component parts has been developed which eliminates the need for frequent shutdowns for removal of alumina sludge and scale from the tanks, thus reducing tank cleaning and maintenance costs. The new etching compound is claimed to solve a number of problems connected with the use of caustic materials for treating aluminium. As aluminium is dissolved in caustic soda solutions, sodium aluminate is formed and hydrogen evolution takes place at the surface of the aluminium. In the case of ordinary caustic solutions, the sodium aluminate is quickly converted to aluminium oxide deposited as sludge and scale, which are hard to dissolve. In most etching plant, frequent shutdowns must therefore be made to remove these accumulations from the tanks. As alumina scale cannot be dissolved by ordinary chemical agents, it must be chipped off, and the life of tank coils or other heating elements is liable to be shortened by excessive hammering. The new etching plant is claimed to solve this major problem of preventing alumina sludge and scale, its action being to hold the sodium aluminate in solution. Steam and other heating costs are reduced by preventing the insulating scale from building-up on the steam coils and heaters, and the difficult task of de-scaling the tanks is eliminated. The solution can be discharged freely like typical alkaline cleaning solution. Another important advantage of the new compound is that it produces a finer and more uniform etch, and foaming of the solution is said to be kept to a minimum.

### ● *RECORDING TAPE OF RUBBER*

Two classes of magnetic recording media have been developed in recent years, i.e., electroplated media and powdered media. Of these, the electroplated media have the advantage that they do not easily deteriorate and give a high signal output. However, in order to realise consistently satisfactory transmission, it is necessary to maintain intimate contact between the recording medium and the magnetic recording and reproducing heads. Attempts made to employ commercial types of coated tapes in various forms of continuous loop mechanisms for special purposes have not met the desired requirements in regard to life, reliability and flexibility of operation, owing to physical failure of the media as a result of tension, flexure and abrasion. It was found that a medium consisting primarily of an elastic rubber band impregnated with magnetic particles was particularly suited to applications requiring long life in continuous service. The compound evolved is decidedly rubber-like in character and consists primarily of synthetic rubber loaded with magnetic iron oxide; it also contains small amounts of lubricants, inhibitors and curing agents. The compound is utilised in the form of seamless bands about $\frac{1}{32}$ to $\frac{1}{8}$ in. thick which are stretched over the surface of cylinders about 10 per cent larger than the bands. When the bands are first taken from the mould, they exhibit a high coefficient of friction. After a few hours, some of the paraffin contained in them migrates to the surface to form a thin, slippery film. If the bands are then put into service, the pole pieces form a polished track, and the continuing migration of paraffin maintains the lubricating film between the band and the pole pieces.

### ● *CERAMIC BACKING RINGS FOR TUBE JOINTS*

In the butt welding of tubes for high-pressure service with the employment of backing rings, the prepared V-groove can be regarded as an open top mould consisting of three sides. Two sides of the weld are the bevelled edges of the tubes to be joined, and the third is the backing under the root of the joint. Since arc welding constitutes a progressive casting process, it is evident that the mould must be tight against the liquid metal deposited in the course of the development of the first pass. The metal deposited by arc welding is in the superheated state and therefore very liquid. A gap at the root of the weld measuring only a few thousandths of an inch will permit metal to find its way in the narrow gap, where it becomes suddenly chilled. This often results in incipient cracks at the root of the weld. In order to eliminate this dangerous condition, a ceramic backing has been developed which is a mixture of sharp sand and cellulose acetate, and which adheres readily to the bore of the tubes to be joined, its setting time being some 30 minutes. The welding heat volatilizes the binder and renders the ring very brittle so that it is shattered by the pounding when dressing the completed first and subsequent passes of the weld. The backing material is thus returned to its original form, that is, sand particles, and these can then be removed by shaking or flushing with water, or may be blown out by air. It would appear that this non-metallic backing offers an entirely new line of approach to an urgent problem which pipe line fabricators would do well to explore.

### ● *LOW-EMISSIVITY COATINGS FOR METALS*

A recent invention aims at the reduction of radiant heat absorption and emission of metal surfaces by applying a special coating of low thermal emissivity. Important applications can be visualized in the gas turbine field, as, for instance, the coating of gas turbine flame tubes for pulverised fuel burning where the heat source is a luminous flame. It is claimed that suitable coatings will be obtained by employing mixtures of 5 to 30 per cent of enamel frit and 95 to 70 per cent of a low-emissivity refractory substance. The

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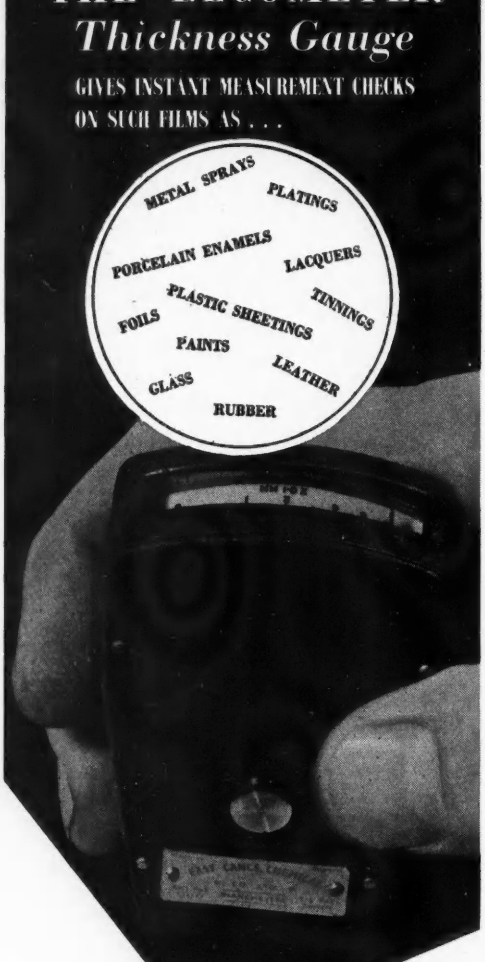


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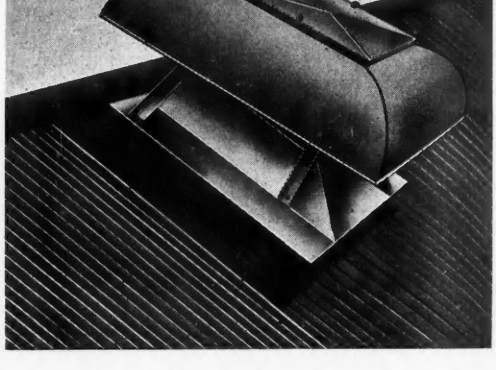

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latter substance should have a coefficient of thermal expansion (when mixed with the enamel frit) which approximates to that of the metal to which the coating is to be applied. As suitable refractory substances, fused silica, stabilised zirconia, fused or recrystallised magnesia or ceria, or suitable mixtures of these materials are mentioned. These substances must be previously powdered to such a fineness that the average particle size is not more than 0·1 mm and not less than 0·001 mm. An interesting feature is that the emissivity of a coating of this type decreases with increasing thickness. However, the adherence of the coating also decreases with increasing thickness and, in order to obtain optimum conditions, coatings of a thickness from 0·003 in. to 0·015 in. should be used. The coatings may be applied by dipping, spraying, or any other convenient means. After drying, the coated part is fired for about 30 minutes at 900 to 1,000° C in a suitable atmosphere. Coatings of this kind have been found to be particularly suitable for heat-resisting alloys containing chromium, or for chromised mild steel surfaces.

### ● *HIGH-SPEED PHOTOGRAPHY IN STEEL PLANT*

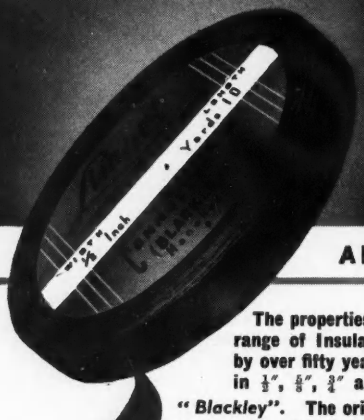
Some of the latest applications of high-speed photography in engineering research are found in the field of steel production. The type of camera used for this purpose was a 16 mm design capable of speeds up to 3500 frames per second, using ordinary or coloured film. Perhaps the most interesting investigation conducted by means of the high-speed camera was the observation of blast furnace combustion zones. This investigation was initiated in the hope that a better understanding of the phenomena taking place in the combustion zone would be obtained by using a high-speed camera to "slow down" the characteristically violent action within the highly luminous field. The exposures were taken through a slightly modified tuyere peepsight with a 2-inch diameter window of silica glass. An interesting observation was that the light intensity within the combustion zone was found to vary over a wide range in less than one minute, as for instance from 140 to 250 foot candles. Valuable information was derived from the photographic records obtained. Large and small angular particles were shown as being blown back and upward in the combustion zone, the small particles travelling at a much greater speed than the large ones. It was found that these particles vary in temperature, some of them being dark red or black in colour, whereas others appear to be bright yellow or white. By comparing the film with photographs of a furnace filled with a coke blank, it was concluded that the majority of the particles observed in the combustion zone of the blast furnace consist of coke.

### ● *NEW GAUGING TECHNIQUE*

A radically new method of production control by what is termed "nuclear gauging" has been introduced in the manufacture of coated abrasives. It is reported that by this method the vital factors of thickness and density of adhesive, abrasive and final adhesive coat can be controlled with an accuracy within one per cent. Nuclear beta-ray gauges, actuated by radioisotopes, continuously assess weight of backing, weight of abrasive, weight after pre-cure and weight after final adhesive application, and thus prevent wastage of the expensive materials used in the processing operation. These gauges are not influenced by outside factors such as temperature, dirt, or humidity. They do not contact the moving sheet at any time. In each gauge, a sealed capsule of radioactive strontium-90 emits beta-rays. As the material being measured moves past the aperture between the sources and the detector unit, which is a special type of ionisation chamber, the amount of radiation passing through the material varies according to the density of the material. The beta-rays penetrating the detector unit ionise a gas and thus create a voltage which provides a recording and controlling signal. As the gauge is calibrated, variations in beta-ray transmission cause changes in signal strength which vary directly with changes in weight per unit area. Recalibration is never necessary, it is claimed. The radioisotope is inspected for emissive power every six months although its life is 30 years.

### ● *NEW USES FOR FERRITES*

Development of various commercial applications of the still quite new ferromagnetic spinels has been under way for only a few years. This material has the mechanical properties of a ceramic; its outstanding characteristic is an extremely high volume resistivity as compared to magnetic core irons. Since eddy currents increase with the frequency of the magnetic field, the use of ferrites has advantages for audio and supersonic frequency ranges. They also have relatively low saturation flux densities, at low or power frequencies. An interesting characteristic from the aspect of production economy is that it is possible to take two halves of a ferrite core and grind the contiguous surfaces so smooth that when placed together, they will form a core having the same permeability as a continuous closed magnetic path of the same dimensions. This eliminates the need for expensive toroidal windings. There have been many attempts in the past to produce tuning of a receiver by means of varying inductance instead of varying capacitance. This requires that the tuning be effective over a frequency range of at least 2:1, with a high "Q" factor. This 2:1 frequency range means that the inductance of the tuned coil must vary over a 4:1 ratio. It has been found that the magnetic ferrites meet



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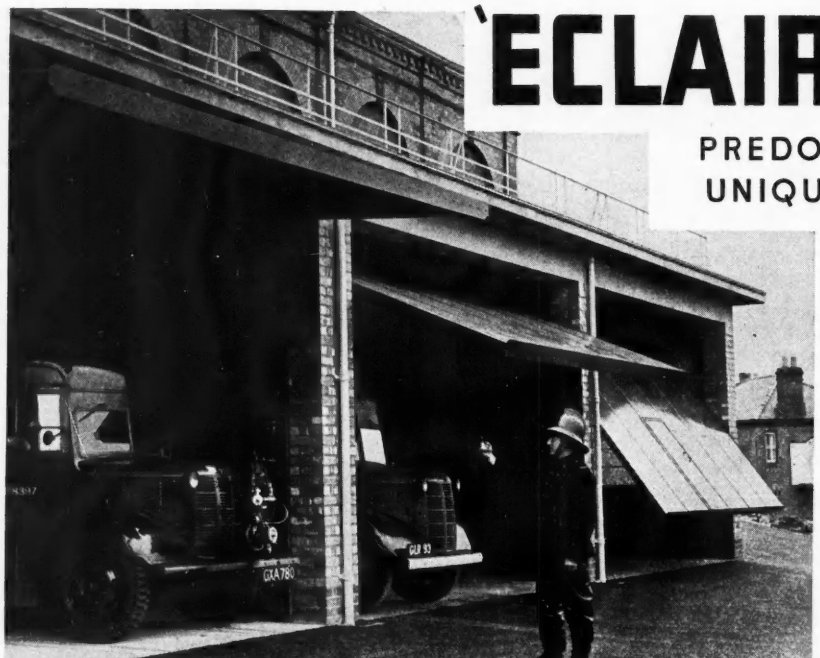

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these requirements, and applications are nearing completion. Inductance variations of coils in the ratio 50:1 and higher are required in magnetic amplifiers and modulator systems. With ferrites, variations as high as 600:1 have been obtained, and the new material may make it possible to expand the possible applications of such systems in higher frequency ranges and in new fields of control.

### ● *FERROMAGNETOGRAPHY*

Ferromagnetography is a new and basic principle in printing. It is a method through which the printed and written text and pictures are reproduced by first forming magnetic images on thin sheets of permanent-magnetic material and then making these images visible by the deposition of tiny ferromagnetic particles. The latter particles are then transferred to a medium such as paper. These steps are analogous to plate making, inking, and printing in the graphic arts. The formation of the magnetic image on the sheet can be carried out in a variety of ways. Thus, for example, a permanent-magnetic stylus, the magnetic field of which is concentrated at the point, can be used for writing and drawing magnetic images. Or, if a permanent-magnetic rod is used, the tip or pole of which is shaped like an alphabetical or numerical character, then by placing the tip on a magnetic sheet, an invisible magnetic image of the character is formed which remains after the rod is removed. Transfer of the image to paper or other media is performed in various ways. One way is by the use of paper coated with an adhesive or bonding agent the adhesive force of which is greater than the magnetic attraction between the particle and the magnetic sheet. Alternatively, instead of removing the particles, the magnetic sheet itself may be coated with printing ink and then used direct for printing. The sheet can be used again for the retention of other images by placing it in a demagnetizing field.

### ● *NICKEL PLATING OF ALUMINIUM*

A novel process for the nickel-plating of aluminium parts is claimed to represent a noteworthy simplification of existing methods. Moreover, the new process permits the production of comparatively thick nickel layers which do not require polishing prior to chromium plating. The new method is said to be applicable to fully mechanised mass production methods, which was not possible with existing processes ; as described, it comprises no more than seven process stages as compared with 28 and 18 stages respectively in older processes. The chromium coatings produced are claimed to be without blemish, provided a nickel layer of at least ten microns is applied, which presents no difficulties. Tenacious adherence of the metal coating to the aluminium is said to be an outstanding characteristic of the new method. Heat exposure of the nickel-plated part to temperatures up to 600° C does not adversely affect the nickel coating. Investigations of the corrosion resistance of plated parts have shown that nickel plating is greatly superior to copper plating. This superiority is considered to be due not only to the smaller potential difference between nickel and aluminium, but also to the density and adherence of the nickel layer. Nickel-plated aluminium can not only be chromium-plated, but can also be plated with copper, brass, or other metals. Where required, copper layers of considerable thickness can be applied over the nickel plating. This is of particular importance in the case of electrical conductors made of aluminium, where copper-plated ends can be joined by ordinary tin soldering.

### ● *CARBON RESTORATION FURNACE*

From the viewpoint of wear and strength, maximum surface hardness and strength of heat-treated parts are of paramount importance. This holds true in particular with regard to such parts as cap screws, bolts, king pins, springs and many types of shafts. In some cases it has been found a commercial proposition to employ a carbon restoration process rather than to machine off decarburised surfaces or to introduce carbon by carburizing or cyaniding. It is obvious that machining represents a waste of material and is an expensive operation. Calorizing and cyaniding, although less expensive than machining, likewise increase overall manufacturing costs. Carbon restoration can be carried out in furnaces in which a suitable atmosphere is maintained under strictly controlled conditions, and large furnaces have been developed in which carbon restoration can be carried out either in batch operation or as a continuous process. These furnaces are so designed as to satisfy the combined requirements of atmosphere-control and flexibility in time-temperature cycles, as well as to accommodate a wide range of products such as bars and coils. Processing times are controlled between one and 24 hours at temperatures ranging from 1400 to 1800° F. Total time in the furnace must, of course, be determined in consideration of the furnace load, operating temperature, depth of decarburization, and other metallurgical factors. In one design, heating is accomplished with the use of alloy radiant tubes, and the furnace is so piped that the radiant tubes can be used for either heating or cooling. In the latter case, air is drawn through the tubes in order to produce a large cooling effect.

***For further information on developments reviewed in THE BLUE PAGES, readers are invited to write to the Editor.***

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VOL. XIII. No. 8. AUGUST, 1952

# The Present and Future of the British Machine Tool Industry

By ROBERT W. ASQUITH, M.I.P.E.*

THE fundamental importance of the machine tool in the march of progress, to the initiated, is accepted as a commonplace; its part in the national economy is taken for granted. But although there is a realisation of its importance amongst those who come into direct contact with the industry, there is on the whole an ignorance on the part of the public generally, many of whom even in these enlightened days have but a vague idea of what a machine tool is.

It is well, therefore, at times to reiterate the statement that machine tools are the foundation of all industrial production and that industrial progress, with its social and economic implications, has been and must continue to be regulated by their evolution and production.

Machine tools are used to produce directly many articles essential to modern existence or to produce other machines which in turn fashion the essential commodities.

The machine tool industry is, therefore, a principal strut in the nation's economic structure. Without a virile machine tool industry national progress must be retarded, and exports, which are the life stream of the nation's economy, would diminish, inevitably resulting in a losing battle against national bankruptcy.

The story of the progress and development of the British machine tool industry right from the pioneering days of the eighteenth century is one of courage, determination and foresight on the part of individual engineers, and many of the well-known firms of today are virtual monuments to the hard work and self-sacrifice of the founders and their immediate associates. The spirit of enterprise from which the industry sprang is still evident in the flourishing organisations of the present day, many of which are conducted by direct descendants of the pioneers.

Whilst the prosperity of the nation from the time of the industrial revolution became more and more dependent upon machine tool development, it took a world war (1914-1918) to bring the responsible authorities to the realisation of this, but, even so, after the urgent needs of the time had been met, little regard was paid to the well-being and survival of the industry.

The imminence of a second world war had the salutary effect of bringing home with greater emphasis to governmental circles the vital importance of a well organised, well equipped and highly productive machine tool industry, and as the international situation deteriorated and the nation was plunged into Armageddon, so was this realisation enhanced. The industry undertook its responsibility with a will and played its full part in the munitions drive which assisted our armed forces to victory.

Following a job well done, the advent of peace saw British machine tool makers immediately and energetically engaged upon the reorganisation of their factories and the application of their enhanced experience and facilities to the interests of reconstruction and the recovery of trade, both at home and overseas.

Not only in pursuit of the prosperity of the industry itself but also in the interests of national recovery and economic survival, much effort and expense was devoted to the re-contacting and development of overseas markets. It should be noted that in normal times British industry does not absorb more than 60 per cent of the production of the machine tool factories, and to maintain the industry at a size which is sound economically and satisfactory from a defence point of view in the event of an emergency, 40 per cent of the industry's output must be exported.

It is disappointing to record the frustration which attended this effort due to comparatively early deterioration of the international political and financial situation. Excellent connections were made, however, and full advantage of the possibilities of overseas markets was being taken prior to the introduction of the present defence programme. It is unfortunate that the results of these efforts have been minimised, or to some extent nullified, by the necessity of priority in the equipment of defence activities.

One outstanding feature of post-war activity has been the intense effort to foster the Canadian market, in pursuance of which the industry participated on an organised scale in the Canadian International Trade Fair at Toronto in 1950 and again in 1951, followed by a token appearance at the C.I.T.F. of 1952. The industry is intensely desirous of serving this Dominion market, and the success of its policy is evidenced by the increase in the backlog of British machine tools for the Canadian market from £300,000 in December 1949, to £3,400,000 in December 1951.

In Germany a vigorous and efficient machine tool industry has been built up once again, which already begins to constitute a very serious competitor to the British machine tool trade. To meet such competition effectively and to ensure the survival of the British machine tool industry as a world supplier, it is essential, while maintaining and improving the British standards which are held in high repute throughout the world, that there must be such increase in efficiency and production as to enable reasonable deliveries to be quoted and prices maintained at a sufficiently attractive level. To induce the overseas buyer to purchase British machines, the high quality of which he appreciates, prices and deliveries quoted must be such as to prevent his thoughts turning in another direction.

Britain has in the past enjoyed certain traditional markets throughout the world, but these are now under threat from revived or new competition. In addition to the re-emergence of Germany as a leading machine tool maker, France, Belgium and Italy are busily engaged on the improvement of their own machine tool production in the interests of defence and international economy. The scope of the British manufacturer must inevitably diminish on that account. Eastern European markets also, which once provided a fruitful source of business for British machine tools, have largely been lost to us. Whether we shall ever regain them is problematical in the light of changed conditions.

Further East, Japan, with its propensity for recovering from the most unpromising conditions, has

(*Concluded on page* 268)

*President of The Machine Tool Trades Association, Chairman and Joint Managing Director of William Asquith Limited, Halifax.

# Machine Tools for Fine Machining

By P. Grodzinski, A.M.I.Mech.E.

*A field of increasing technical importance is that of final and finish machining; a short technical survey may indicate the possibilities and difficulties in this particular field.*

The tendency today is to carry out preforming and shaping by chipless production methods (fine casting, forging, stamping, deep drawing, plastic moulding) and thus to eliminate the production of chips or waste which cannot be easily recovered. These methods have been highly developed. For the last finishing operations, only very little material has to be removed in order to improve dimensional accuracy and surface finish. Whilst "finishing" in traditional engineering was done by hand (filing and scraping), the unanimous opinion today is that these last finishing operations, sometimes even performed after grinding, have to be made by the modern finishing processes, such as fine boring, fine turning, fine grinding, lapping, honing or superfinishing. It is outside the framework of this article to discuss the basic principles of these methods, which are already well covered by modern textbooks and reference works. A few modern machines representative of various types will be described in the following.

## Fine Boring Machines.

The Wiedemann single- and two-spindle fine boring machines, Fig. 1, use the unit system of construction. The boring head moves axially along bedways. The boring spindle runs in adjustable anti-friction bearings and has a maximum speed of 4000 rpm, the feed ranging from 0·0003 to 0·004 in./rev. of the spindle. A rapid traverse of the boring head is provided for at the rate of 10 in./min., this being produced by a separate motor. The machine can be used with semi- or fully-automatic operation. In the latter case, the boring head moves with rapid traverse until the tool is close to the work, when the spindle starts to rotate and the slow feed is engaged. At the end of the cutting stroke, the spindle is automatically stopped. In the machine with two spindle heads, these are controlled independently of each other. Workpieces can be set up on the table opposite one spindle, while fine boring is carried out by the other. The boring heads and slide-way members are separate units and may be mounted on beds to form multi-way machines for special operations.

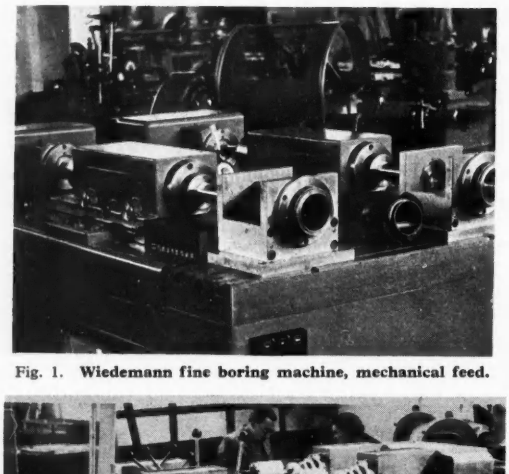

Fig. 1. **Wiedemann fine boring machine, mechanical feed.**

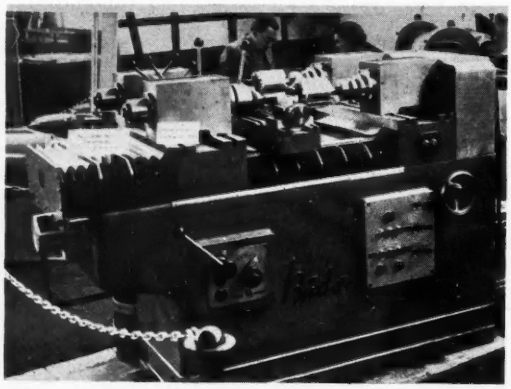

Fig. 2. **Buecher fine boring machine, hydraulically controlled.**

In the Buecher hydraulically controlled fine boring machines, Fig. 2, speed and feed can be varied within wide limits; the two-spindle machine can be equipped for fine turning and facing operations by an additional tool rest with fine adjustment.

In the French Diamanta I precision boring machine, Fig. 3, the spindles are mounted in slightly eccentric relation to the head in order to make micrometric centering of the tool possible. Two types of spindle heads are available, one for high speeds and high duty (working in steel and cast iron) and another for very high speeds and light duty (working in non-ferrous metals and plastics). The first-mentioned head has a lead-bronze bearing with conical faces; at the back, the spindle is held in two precision bearings. A patented device permits automatic balancing of the bearing clearance as a function of the speed, temperature and load.

The light-duty spindle runs entirely on high-precision bearings, which are carefully selected and lapped. The bearing clearance is automatically adjusted. The feeds are obtained from an independent

Fig. 3. **Déragne "Diamanta I" precision boring machine with hydraulic feed motion.**

motor connected with a speed reduction gear. The connection is by worm gear, the helical gear pinions being in direct contact with the rack underneath the table. The rack is fixed to a hydraulic cylinder running on slides in the machine housing. The table is moved by the piston heads and in this way is completely isolated from the drive. Rapid return is by hand. The machine can be operated manually or semi-automatically. In the latter case, an electric control is used.

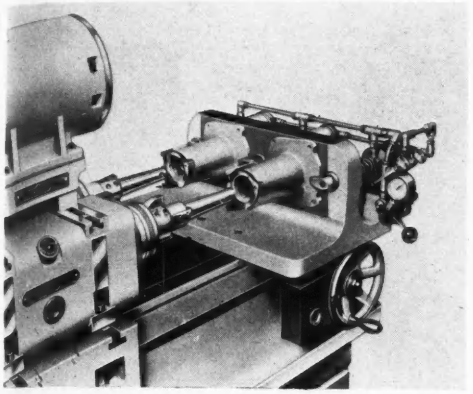

Fig. 4. **Boneham & Turner fine boring machine. Rough and finish boring of cone seats for valve bodies.**

The Boneham & Turner fine boring machine, Fig. 4, is provided with mechanical feed. The boring spindle runs in precision ball bearings and the spindle heads maintain a high degree of accuracy for a long period of time. The bed has V- and flat guides and is carefully scraped ; the table also has V-shaped supporting faces and, similarly to the bed, is accurately scraped. The table movement is performed by a hardened and ground lead screw, which passes through a nut of large dimensions. The lead screw runs in precision ball bearings and is driven through a coupling and worm gear by a $\frac{3}{4}$-hp motor. A V-belt drive with exchangeable pulleys is arranged between the motor and drive. Thus, by changing the pulleys, table feeds between 6·35 and 150 mm/min are obtained. The motor armature runs in precision ball bearings, and the armature as well as the belt pulley are dynamically balanced. As already mentioned, the main spindle runs in precision ball bearings, pre-loaded to exclude axial and radial play. The spindle face and the flanges, therefore, have no greater inaccuracy than 2 microns. Boring bars can be adapted to the spindle. The spindles are driven by a special motor and V-belt drive. A mechanical brake automatically stops the spindle at the end of the operation. Spindle speeds up to 7,500 rpm can be obtained, and up to 4 boring heads can be arranged on the bridge of the standard machine. Fig. 4 shows a single-ended fine boring machine with a fixture for the rough and finish boring of an aluminium pump housing. The machine has a hand-operated cross-slide carrying two boring bars, one of which is used for rough boring of the casting. After this operation, the second boring bar is used for finish boring. The first tool is sintered-carbide-tipped, the second a shaped diamond tool.

The Precimax precision boring, turning and facing machines, Fig. 5, are supplied as single-ended and double-ended machines with 1 to 4 spindles, parallel to one another. The spindle heads are mounted on a bridge, whilst the table is underneath the hydraulically operated traversing movement. The oil pressure is supplied by an independent pump unit. The pump has two sections, one being a large-volume pump for rapid traverse movement and the other being a small delivery pump for boring and facing feeds. A cycle-selector switch allows of changing over from automatic to hand reverse at the table end. The boring heads are made in various sizes to cover a wide range of boring diameters and speeds. The spindles run in high-precision ball bearings and are dynamically balanced. Special precautions are taken to exclude dirt from the bearings. The spindles are driven by endless V-belts from dynamically balanced motors, also running in precision bearings. The spindle pulleys can easily be exchanged. A smooth-acting and efficient electric motor brake allows of stopping the spindle immediately. Two of these fine boring machines will be shown at the forthcoming International Machine Tool Exhibition in London. One machine will show the boring of tappet guide holes in a Jaguar cylinder head. A double-spindle machine is shown for turning differential castings mounted on mandrels for Morris engines. A special fixture carrying the electric push-button controls is mounted on the right-hand bridge. Furthermore, several bridges with fine boring heads mounted will be shown. One of these is used for machining valve seats and guide bars in a Rolls-Royce cylinder head.

The well known Vomag fine boring machine, Fig. 6, which has been developed in Germany over a period of 20 years, is now produced by the Alfing-Kessler Works, and these machines have already been shown at a number of Continental exhibitions. A special feature of these machines is the hydraulic feed and the mounting of the spindles in sleeve bearings. The bearing clearance is reduced to 0·003 to 0·004 in., even with high spindle speeds. Lubrication is by low-pressure oil. During the last few years, unit types of design have been developed, according to which special machines can be made up of a number of units. Besides boring and multiple boring operations, turning and facing operations

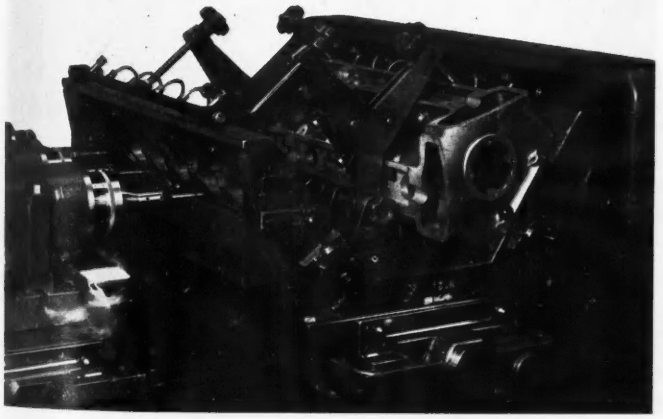

Fig. 5. **Precimax precision boring machine with 3 spindles. Cylinder head loaded in position on fixture. This is mounted on an indexing cross-slide.**

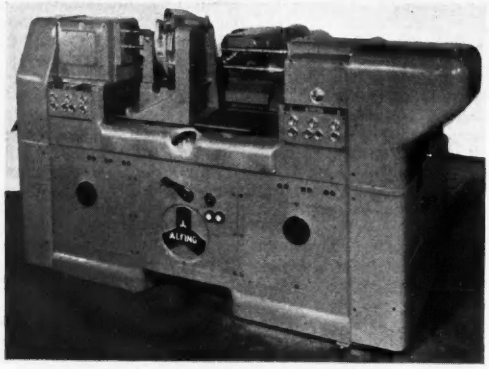

Fig. 6. **Vomag fine boring machine.**

can also be carried out, for which special equipment has been developed.

FINE TURNING MACHINES.

One of the first special diamond lathes, characterised by relieving the main spindle from the belt pull, and without gears in the spindle drive, as well as in the drive of the feed gear, was the Boley diamond lathe, which, after some interruption shortly after the last War, is now again on the market (Fig. 7). A particular feature is the closed water-cooled heavy bearings, which run with remarkably small clearance. The thrust is also taken by a sliding bearing near the front spindle.

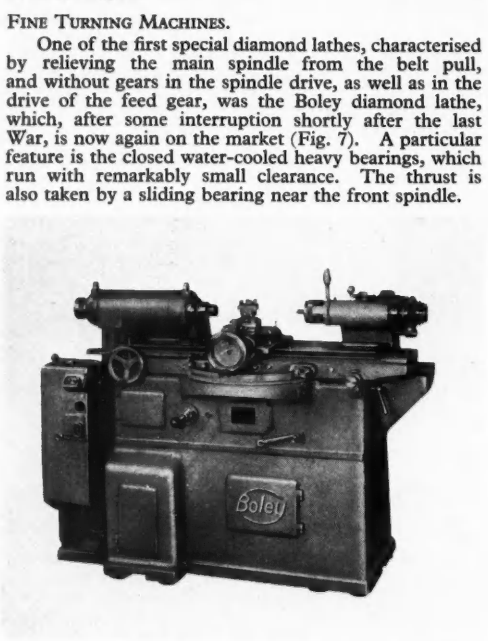


Fig. 7. **Boley diamond lathe.**

The Bryant Symons diamond lathe, Fig. 8, is available as a standard and as a heavier model. A horizontal face of the bed takes the spindle head, tailstock, and the main rotary support for the main slide. A special feature is that the main slide can be adjusted in the axial direction and perpendicularly to it. The driving pulley runs in two ball bearings and drives the spindle running in independent bearings by means of a self-adjusting coupling. The spindle is nitrided, hardened, ground and superfinished. The driving belt pulley is of aluminium ; it is well balanced and driven by the motor through an endless V-belt. The spindle runs in two adjustable white-metal bearings of large length, radial and axial adjustment being provided. The bearings are lubricated by drip feed lubrication, the oil being circulated in the spindle bearings by a pump. The oil pipe contains an effective oil filter system. The spindle is driven by endless V-belts from a pole-changing motor with three speeds. The motor is placed outside the machine bed ; by changing the pulleys, six spindle speeds are obtainable with an additional low speed.

The rotating tailstock centre is arranged in a spring-

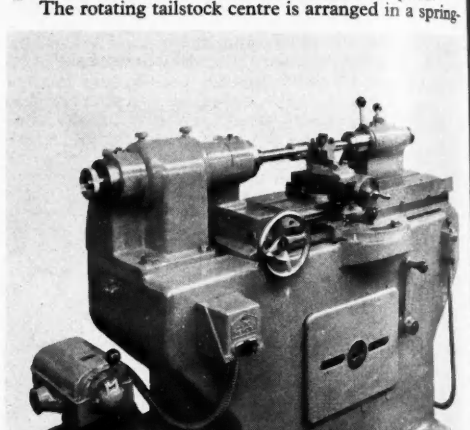

Fig. 8. **Bryant Symons diamond lathe.**

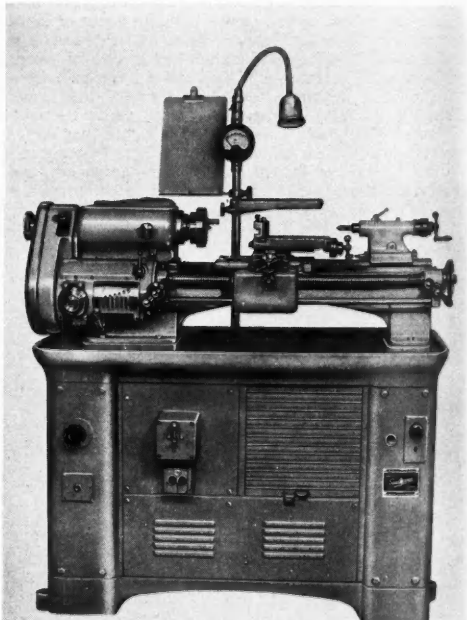

Fig. 9. **3½ in. centre height Cromwell lathe.**

loaded shell. The feed movement is derived, in each position of the main slide, from the lead screw, which itself is driven through endless round belts and a worm gear from the main spindle. Three different working feeds are provided. Further, a rapid feed is provided to bring the table from one position into the other, this being effected by a special motor.

The 3½ in. Cromwell lathe, Fig. 9, has spindle speeds infinitely variable by means of a Ward-Leonard set. A pilot lamp indicates when the motor generator rotates. In this condition, the main spindle can be started, braked or reversed by operation of a switch. The spindle is rapidly stopped by a dynamic brake. When reversing, a small time lag is allowed for stopping the spindle. The spindle speed can change from very low speeds up to a maximum speed of 2000 rpm. The speeds are indicated on a speedometer opposite the operator. Limit switches prevent the slide from running against the spindle head; at the same time, the spindle rotation is stopped. The spindle runs in accurately adjustable sleeve bearings consisting of slotted bearing bushes with external cones. The driving pulley is mounted independently of the spindle in ball bearings, thus eliminating any influence of the belt pull. A jaw coupling transmits the rotation of the pulley to the main spindle. In addition, a reduction gear running in oil is provided. The spindle nose has a cone and a flat face, which is said to be the only safe means of ensuring concentricity. The two main spindle bearings are of white-metal and diamond-bored. The lathe is very useful for diamond turning; tests made some years ago on a machine just finished, which was not fixed to the workshop floor, gave surface finishes of 3 to 5 micro-in. average height[1].

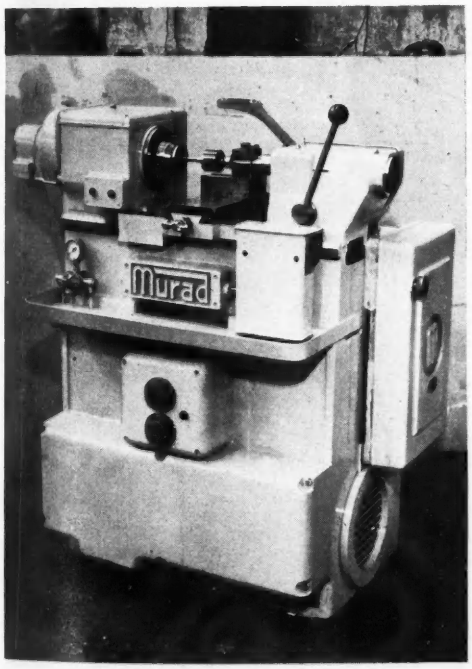


Fig. 10. **Murad commutator lathe.**

Murad Developments Ltd. have produced a special lathe for turning the commutators of small electric motors (Fig. 10). The machine is expected to effect a saving of possibly 4 operators. A main motor drive is provided for the main spindle and a separate motor drive for the feed gear. An upper guard contains the isolating switch and a switch which enables the saddle to be inched in either direction along the bed. Electric brakes are fitted so as to stop the motors as required. The cycle of movement on the tool slide is controlled by a cam driven by a train of pick-off gears from the feed gear motor, permitting variations in the quick approach and feed relationships as well as in the cycle of operations. The depth of cut can be adjusted by a micron dial, and fine adjustments along the bed are possible through the auxiliary slide mounted on the main cross-slide. The tool post is adjustable in height. The bearings are automatically lubricated. The operator is protected from flying chips by a swinging transparent guard, which automatically moves into position at the start of the working cycle and withdraws at the end[2].

## Grinding.

Whilst standard grinding machines do not fall within the scope of this survey, some further developed grinding methods may be referred to which produce mirror-finish surfaces. In the method developed by F. Cattin[3], mirror finish is obtained on standard machines by a succession of grinding operations with wheels of increasingly fine grain size. Usually, three operations are provided, an ordinary finish being obtained in the second operation with a medium-grade 80-mesh grinding wheel, either silicon carbide or aluminium oxide being used. Silicon carbide is employed for grinding soft materials such as unhardened mild steel, cast iron, bronze, etc. Metals of high tensile strength, hardened, carburised, alloyed or unalloyed, are ground with aluminium oxide wheels. In the second finishing operation, grinding wheels of 500 mesh are used, whilst in the third finishing operation, wheels finer than 500-mesh are employed, the abrasive being aluminium oxide or a specified polishing powder. Bakelite or vitrified bonding is used, depending on the work. When an extremely fine mirror finish is desired, an intermediate operation is introduced between the first and second operation, using a wheel of 200 mesh. The allowance for the superfine grinding operation should not exceed 2 to 3 microns. The mirror-finish grinding operation does not take more than 1 to 2 microns off the diameter. In the superfine grinding operations, the usual grinding speed is reduced to 14 to 17 metres/sec. The peripheral speed of the workpiece must be reduced to 6 or 7 m/min. Of greatest importance is the truing of the wheels and the filtering of the coolant.

In grinding machines for obtaining mirror finish, the fluid bearing after P. Gérard has been applied with great success[4]. Oil is pumped under pressure through a number of holes and distributed over relatively deep cavities. If the shaft is displaced by the action of external forces, the gaps are reduced and the pressure is increased. Thus, the shaft has a self-centering action and the surrounding fluid acts as an elastic medium. There is no direct contact between shaft and bearing as long as the fluid is supplied by the pump. These bearings have been applied to a number of grinding machines, particularly for the grinding of large rolls which are receiving a final finish.

A machine which enables the production of mirror-finished surfaces is the cylindrical grinder of Kummer Frères (Fig. 11). The table is driven hydraulically and slides on automatically lubricated V-guides. The reversing time can be adjusted independently on each side of the traverse. The workhead, driven by a d.c. motor, has speeds variable from 110 to 1100 rpm by a Ward-Leonard set. The work spindle is driven by a V-belt, the workhead being totally enclosed. The wheel spindle runs in bronze bearings and is oil-lubricated through a gear pump. The belt pulley drives the spindle through a semi-elastic coupling. Operation of the machine is by a single lever.

One of the latest advancements in superfinishing consists in utilising resonance effects, by means of which

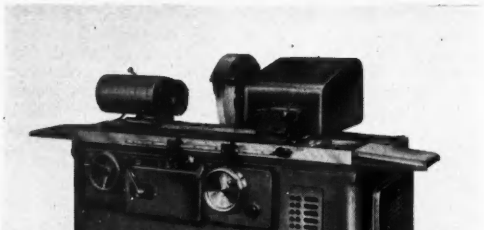

Fig. 11. **Precision grinder, Kummer Frères.**

oscillation frequencies between 1500 and 3000 strokes/min can be continuously produced[5]. In the machines designed by C. Berstecher for the Laboratoire Centrale d'Armement, one end of a torsion bar is rigidly held in a solid block, whilst the other end is freely supported on a bearing block and carries a bell-crank lever (Fig. 12a and b). One bearing of this lever is in contact with a vibrator, consisting of a cam driven by an electric motor through a gear box. The speed of the motor can be

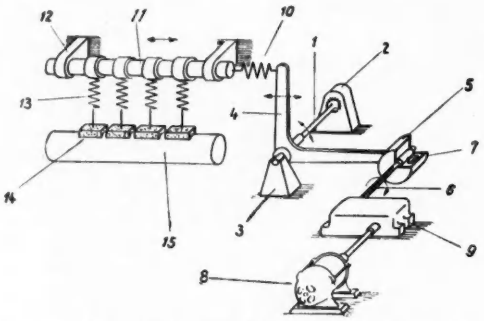


Fig. 12a. **Principle of superfinishing, agitation by torsion bar [1].**

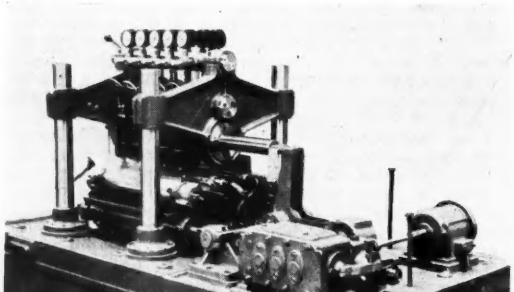

Fig. 12b. **View of upper part of superfinishing machine (Laboratoire Centrale d'Armement).**

controlled either mechanically or electrically. The flexible shaft isolates the gearbox from vibrations, the other end of the lever acting through a leaf spring on a shaft carrying the tools. The parts to be machined are contacted by superfinishing stones, the pressure being produced by springs or by pneumatic or hydraulic devices. The shaft can oscillate only in the horizontal direction, the frequency and amplitude of the vibrations of the shaft being controlled by the speed of the cam. The complicated movements of the usual superfinishing methods are thus replaced by a linear motion which is easily controlled.

In addition to devices where the cylindrical workpiece is situated on rollers (Fig. 12b), machines exist in which the workpiece is mounted between centres and there are also internal superfinishing attachments now under development.

The above principle is highly suitable for superfinishing rollers for roller bearings as well as pistons and piston pins. In one example, 360 piston pins of 22 mm diameter, 85 mm in length, were rough finished per hour, i.e., 10 seconds per part. About 840 piston pins can be fine-finished in one hour, i.e., 4 sec per part, 0·02 mm being removed from the diameter. An original out-of-roundness of 7 to 10 microns before superfinishing was not measurable afterwards. In general, aluminium oxide and silicon carbide abrasive sticks are used, but experiments with diamond honing sticks are also being carried out.

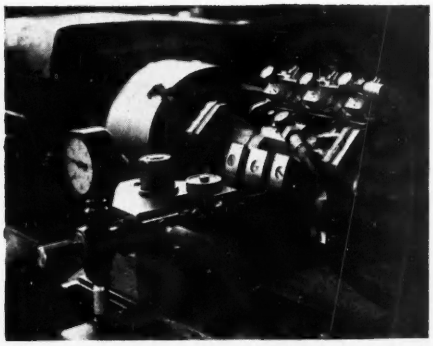

Fig. 13. **Superfinishing method " Schwingschleifen."**

Wieck & Heim KG developed a new oscillating grinding method known as " Schwingschleifen " (Fig. 13). The honing stones are movable on a bar which is vibrated by means of a band suspension and is connected

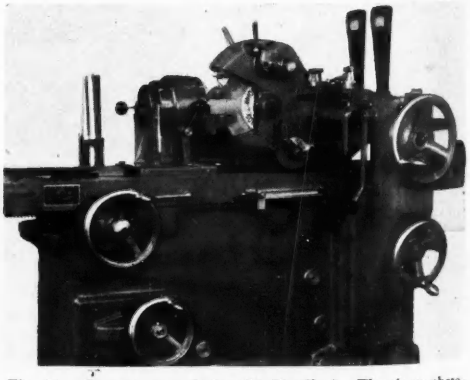

Fig. 14. **Gap gauge grinder (E. Mueller).** The above photograph shows the machine equipped with special fixtures for grinding turbine blades.

with the vibrating system, the vibrations being produced by compressed air. Care is taken that no unbalanced forces are exerted on the machine body. The pressure on the stones is also obtained pneumatically. Surface finish of less than 1 micron maximum height is claimed.

The diesel engine manufacturers, Kloeckner-Humbold-Deutz AG, have already produced 10,000 cam shafts using this device. The grinding time for pre-grinding and finish-grinding is about 1·5 min, i.e., 30 sec for each bearing.

Gebr. Loewe, Düsseldorf, have developed a new hydraulic super-finishing device which can be mounted on a lathe. C. Berstecher has developed an interesting honing head for superfinishing. To the usual honing movement, i.e., rotary and reciprocating movement, a third motion has been added, i.e., a high-speed vibrating movement. It is said that with this device the honing is made independent of the touch and experience of the operator. The pressure acts on several edges of the honing sticks and short broken chips are produced which prevent clogging of the honing sticks. A mat surface of run-in cylinders with scratches running parallel to the axis can be obtained with this new device by stopping the rotary movement at the end of the honing operation. After each double stroke of the honing tool, the oscillating movement is indexed for $\frac{1}{4}$ widths of the stone.

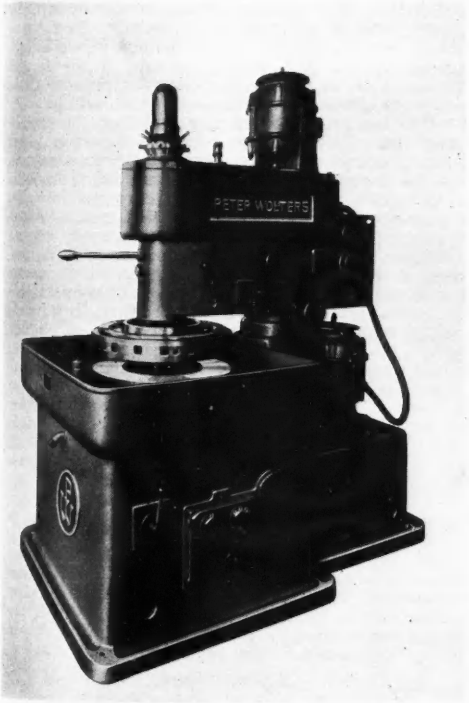


Fig. 15. **Peter Wolters flat lapping machine.**

The same inventor has developed a honing device for large cylinders which is fixed to the outside of the cylinder and travels along the cylinder with a small inclination of the grinding wheels. This permits of finishing machine cylinders *in situ* without removing the heavy cylinders from their bearings[6].

The gap gauge grinder, Fig. 14, is intended for the mass production to close limits of parts such as gap gauges, flat gauges, forks, plungers, and connecting rods. The movements in the machine are sub-divided

Fig. 16. **"Lapmaster" one-sided lapping machine.**

so that the work-slide performs the longitudinal movement, and the grinding head the traverse movement. During the finish-grinding operation, a fine measuring instrument permits of observing immediately the size of the gap, thus eliminating all intermediate gauging. The grinding wheel is of double T-section, and two pairs of truing diamonds are fitted to its cover, one pair being for preparation for roughing and form-truing, and the other for preparation for finish-truing. When the grinding wheel is trued with the roughing diamonds, the finish diamonds must be re-set by the same amount. The holder of the finishing diamonds is connected with the carrier of the fine measuring instruments. Therefore, with this device very accurate gap gauges can be produced without intermediate gauging.

LAPPING.

Whilst the methods hitherto described make use of bonded abrasives, in the lapping process small amounts of material are removed by rubbing the workpiece with irregular movements over flat lapping plates provided with loose abrasive and a lubricant. Trueness of surfaces is obtained through the continuous flow of free abrasive grains rolling between the mating surfaces. The unit pressure is light, and the speed is low, less than 600 fpm. The heat generated is therefore small. Silicon carbide and aluminium oxide abrasives are widely employed. Occasionally boron carbide, but rarely diamond dust, is used. Silicon carbide of the same grain size as aluminium oxide cuts faster but produces a rougher finish. It is therefore generally restricted to lapping of hard steel, sintered carbide, cast alloy, etc.

In ordinary lapping machines, the part is moved or rolled between two flat lap plates. In the Newall lapping machine, the upper lapping disc is stationary but is provided with angular adjustment. Whereas the lower lapping disc rotates at a speed of 60 rpm, the workpiece holder rotates at a lower speed to effect a lapping action of both lapping discs. The reduced workpiece speed is said to ensure a uniform wear of the lapping disc and, therefore, to reduce the necessity of frequent truing. The lapping discs are made of a soft fine-grained cast iron. The lower lapping disc and the tool holder are driven through a worm gear submerged in oil. The mechanism for lifting the upper spindle is well protected. Five machines of different sizes are being manufactured at present.

The lapping machine (Fig. 15) is built in two sizes for disc diameters of 350 and 600 mm. The smallest diameter to be lapped is 3 mm, the largest 60 mm, or

100 mm. The lower disc is of fixed height and driven through a hollow shaft at speeds between 40 and 110 rpm. The upper disc can be adjusted in the axial direction and can also be lifted. The upper disc can adjust itself to the workpieces. It can be driven in the opposite direction to the lower disc, held in a fixed position or dragged by the lower disc. The cage carrying the workpieces is driven by an eccentric. The pressure between the lapping discs is produced mechanically.

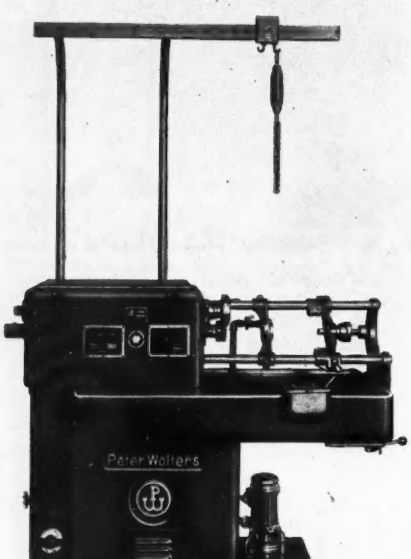


Fig. 17. **Peter Wolters internal lapping machine.**

In other lapping machines, the upper lapping plate also rotates, and positively controlled work holders for lapping are increasingly used, particularly for the lapping of quartz[7]. New production processes permit of producing quartz discs of a thickness down to 0·001 in., which cannot be produced by conventional methods[8].

A new departure is a lapping machine, Fig. 16, which only laps one side of the workpiece, a method comparable to metallographic lapping. Special alloy cast iron lapping plates are used whilst the workpieces are contained in conditioning or wear rings made from the same material as the plates. A work separator (laminated phenol formaldehyde) fits within the wear ring and keeps the workpieces apart, but allows them to rotate. Pressure plates may be applied for parts which are too light. Further, a variable pressure is possible. A constant flow of fresh, sharp, abrasive grains is maintained. The compound flows through a metering orifice in the power agitator, controlled by a solenoid valve ; thus, flow starts and stops with the operation of the machine. These machines work according to an automatic cycle.

Compared with the hand-lapping method for finishing holes, machine-lapping has been introduced for some time (Fig. 17). In this method, a uniform lapping pressure is caused between lapping shell and wall of the hole. In order to obtain high accuracy of the order of 1 micron, the workpieces are not clamped but are centred by hand on the lapping machine and also reciprocated by hand.


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## THE INFLUENCE OF SOUND AND ULTRASOUND ON ELECTRO-CHEMICAL PROCESSES

(*Continued from p.* 260)

at the cathode under the influence of ultrasound are interpreted by the authors as follows : the large depolarisation jump always occurs simultaneously with the hissing noise of cavitation, where, owing to the force of sound pressure, small voids are formed in the liquid, subject only to the vapour pressure of the liquid. Dissolved or other gases can easily diffuse into these voids, the ultrasound thus having a suction effect.

The intensity-potential curves can now be simply explained. Cavitation occurs above a certain lower limit of sound intensity. From this point onwards, the gas generated at the cathode can diffuse into the voids, and is therefore immediately removed from the electrode. A sudden potential drop results, which approximately coincides with the appearance of the cavitation noise. Increasing the intensity further will make no difference to the potential drop, as the vacuum inside the cavities is already the maximum value that can be reached in water. Hence, the practically constant " ultrasound potential " is accounted for. A sudden jump can, however, only be expected if the current density and hence the speed of gas evolution is small enough for it to be quickly removed, even at a moderate cavitation. At higher current densities the transition region will therefore be less steep. The total height of the potential jump is unaffected, as at sufficiently high sound intensities the cavitation will once more be great enough to collect all the gas evolved at the cathode.

From the above interpretation it follows that the height of the polarisation jump is fairly independent of the material of the cathode. The exceptional case of magnesium can be understood, as magnesium liberates considerable quantities of hydrogen even in the absence of current. It therefore behaves as another metal at higher current densities, i.e., it will not exhibit the depolarisation jump, as the freely liberated hydrogen masks the sound and cavitation effect.

(*To be continued*)


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# Reduction of Wear and Corrosion by Suitable Design and Choice of Materials

By O. NIEZOLDI. (From *Konstruktion*, Vol. 4, No. 5, May 1952, pp. 145-148, 15 illustrations.)

CONSIDERATIONS of design must be combined with correct choice of materials if structural components in engineering are to withstand corrosion and wear successfully. Thus, *fire bars* for boilers are subject to strong corrosive attack and wear ; only the combination

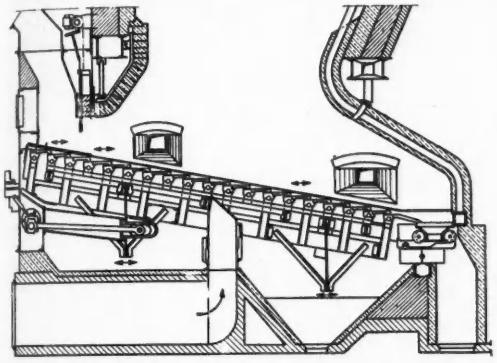


Fig. 1. **Oscillating multiple-retort fire grate, Borsig type.**

of a suitable arrangement of air channels to reduce the working temperature with a choice of cast iron of favourable composition and metallographic structure can guarantee a long service life. The heavy wear of *travelling grate rollers* can effectively be reduced by case or flame hardening or nitriding. Flame hardening permits the use of a 0·4 to 0·6 per cent plain carbon steel whilst alloy steels are required for nitriding. On the other hand, a suitable change of design may also prevent wear of the moving parts ; a grate suspended in pendulum fashion by elastic strips is practically free from wear

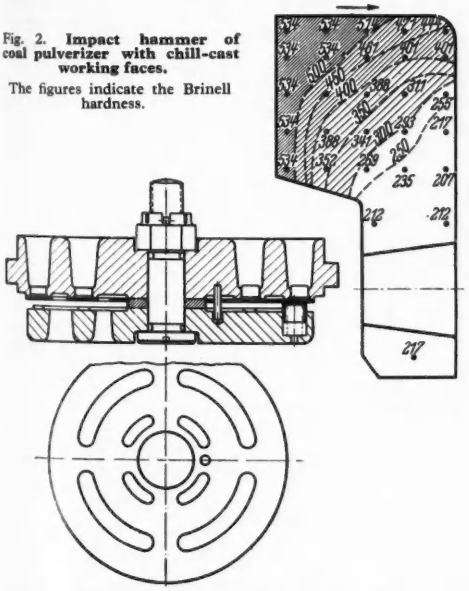


Fig. 2. **Impact hammer of coal pulverizer with chill-cast working faces.**
The figures indicate the Brinell hardness.



Fig. 3. **Low-lift plate valve, old design.**

damage and has now been successfully operated for about 10 years (Fig. 1). The *impact hammer of a coal pulverizer* is usually made of 10 per cent manganese steel to resist wear. This material did not give complete satisfaction and a substitute was required during the war years. A special cast iron was developed and the working surfaces of the hammer were hardened by chill casting (Fig. 2). Nowadays, these hammers are also made of flame-hardened steel.

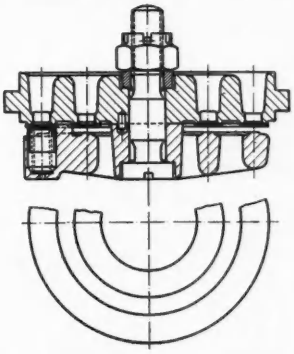


Fig. 4. **Low-lift plate valve, new design.**

Failures of *valve discs* of low-lift plate valves in compressors have been eliminated by a change in design. Previously, the disc was guided by spigot and pin (Fig. 3) and wore rapidly, whilst the new design consists of several concentric rings, spigotted but otherwise freely movable (Fig. 4) and has proved satisfactory. The peculiarities of wear phenomena are well shown in the following example : Similar valve discs of highly normalized Cr-Ni-steel were designed to work against guiding plungers of light alloys made adjustable to compensate for the expected wear of the plunger surface. However, not the plunger but the steel valve disc wore away because the difference in hardness was excessive. Very fine particles worn off the steel disc embedded themselves in the light alloy and exerted a grinding effect on the disc. The wear of the sealing surfaces of *steam engine slide valves* can largely be reduced by the choice of suitable materials, e.g., nitrided steels, or nitrided stainless steels where corrosion must be expected, or steel with stellite surfaces deposited by welding and perhaps also finally nitrided. Wear of piston rods due to *piston flutter* in vertical steam engines

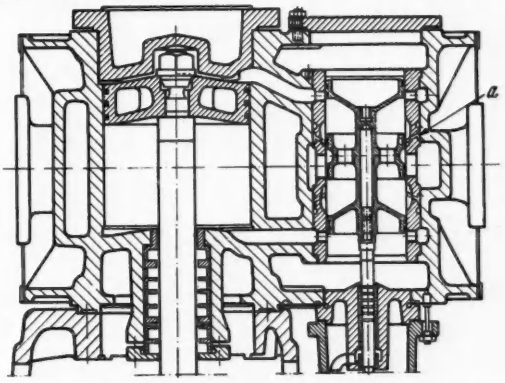



Fig. 5. **Section through steam engine cylinder with piston valve.**
*a* = oil channel.

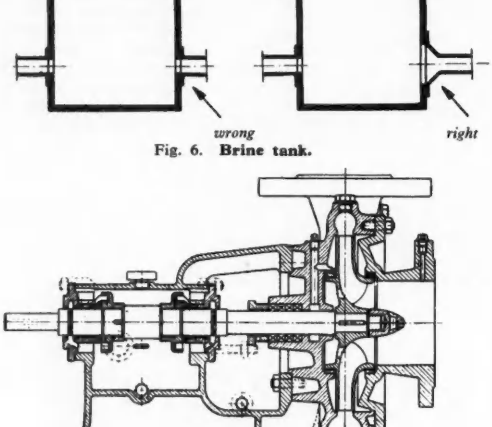



Fig. 6. **Brine tank.**

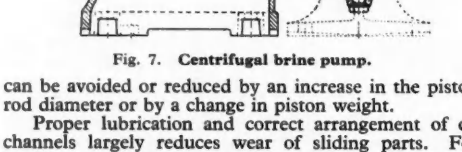


Fig. 7. **Centrifugal brine pump.**

can be avoided or reduced by an increase in the piston rod diameter or by a change in piston weight.

Proper lubrication and correct arrangement of oil channels largely reduces wear of sliding parts. For instance, a compressor for vapours containing benzine showed heavy wear because the vapours dissolved and eliminated the oil films. Wear was avoided, however, by a suitable rearrangement of the vapour inlet. Fig. 5 shows a steam engine with piston valve. Proper positioning of the oil channels *a* essentially reduces wear of the valve piston rings. The valve liner is pressed into the housing with copper rings as oil seals between liner and housing. These rings are situated on the low-pressure side of the oil channels so that oil in the ring channels cannot accidentally be blown into the engine cylinder by the high-pressure inlet steam.

The following examples show how corrosion and erosion can be avoided or minimised. Strong corrosion or erosion near the outlet flange of a brine tank was eliminated simply by a change in shape of the outlet tube (Fig. 6). A *centrifugal brine pump* (Fig. 7) with a housing of cast iron and a bronze impeller showed strong corrosion due to electro-chemical cell formation. Both housing and impeller must be made of the same material if corrosion is to be avoided; even a combination of bronze with steel or of stainless steel with ordinary steel would lead to corrosion. In another example, the entire inner surface of a vessel containing the sump of a $CO_2$-*purifier* (Fig. 8) showed characteristic blisters of differing sizes up to 4 in. in diameter. When the vessel was cut open, the blisters were found to be filled with gas at a high pressure. The sump water, saturated with $CO_2$, had an acid effect and attacked the wall of the vessel. Nascent hydrogen in atomic form diffused into the material, collected at a certain depth, particularly at slag inclusions, and re-combined to molecular hydrogen which could not diffuse out of the cavity. It collected, raised the gas pressure up to about 1500 psi and thus caused the blisters shown in Fig. 8. The use of appropriate materials or inner linings remedied the trouble. *Vertical pressure receivers* have often been built with dished ends curving into the receiver (Fig. 9, top); no special stand is required with this design. However, such receivers can never be drained completely and will show corrosion at places where drainage is impossible (see arrow of Fig. 9). Modern constructions have abandoned this design.

The partitions of *absorption columns* often contain several hundred bell caps for a better distribution of the gas to be absorbed. The caps had been fastened by a stud-and-nut connection which corroded so strongly that, after a short service life, the caps could no longer be removed. The cotter connection shown in Fig. 10, however, has proved satisfactory. In the manufacture of *artificial silk*, copper sulphate solutions are circulated by pumps. Failure of pump plungers led to the adoption of nitrided steel plungers. The nitrided layer, however, though apparently resistant at first, was completely perforated after 24 hours. A slightly ammoniacal copper sulphate solution eliminated the trouble.

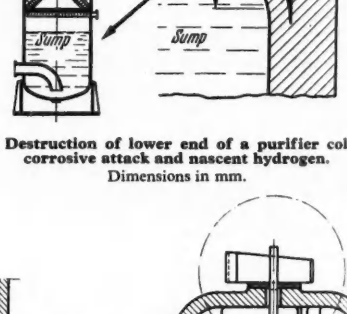



Fig. 8. **Destruction of lower end of a purifier column by corrosive attack and nascent hydrogen.**
Dimensions in mm.

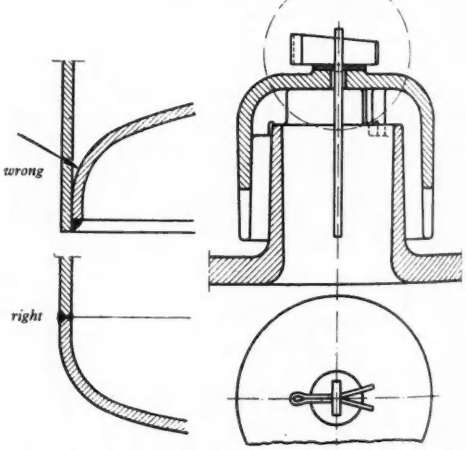



Fig. 9. (left) **Arrangement of bottom dished end in vertical pressure receiver.**

Fig. 10. (right) **Bell cap for absorption columns showing cotter connection replacing the old screw connection.**

# Model Techniques for Evaluating Electro-Thermal Installations

By G. V. DERSHVARTZ and M. Y. SMELYANSKIY. (From *Elektrichestvo*, No. 10, 1951, pp. 47-50)

*Among the fields of practical design, electro-thermal installations are still lacking to a large extent in really useful and effective methods of analysis. Large savings can be achieved by the elimination of trial and error through the use of model techniques. As usual in engineering work, model laws cannot be rigorously applied. Fruitful compromise needs sound engineering judgment and experience in the application of model testing in each particular field. The author restates the laws of similarity governing electro-thermal installations, shows the difficulties in their application, and gives practical recommendation on materials, scale and frequency to be used in model tests of induction and arc furnaces.*

THE theory of physical similarity has found many applications in heat engineering, and in hydro- and aerodynamics, but has not so far been sufficiently exploited in electrical engineering. Particularly in electro-thermal installations, it is highly desirable to be able to experiment upon inexpensive but representative models.

The experimental worker may wish to know the answers to the following two questions : (1) What are the laws which the reduced scale model must obey in order to ensure the similarity between the electrical phenomena in the model and those in the original ? (2) What are the methods to be used for converting the experimental data obtained from model experiments into data for the full-scale project ?

The problems in electrical heating which can be experimentally investigated on the basis of similarity are primarily problems related to the properties of the electro-magnetic field. In particular, similarity is by no means tied to linear relations between fundamental field magnitudes, and can therefore be applied to magnetic fields in ferrous materials.

The similarity of electro-magnetic fields demands geometrical similarity between model and original, but also the fulfilment of other conditions. Even in static electric or magnetic fields, geometrical similarity must be supplemented by proportionality between the physical constants ($\epsilon$, $\mu$) of the field medium. In the similarity of changing electric or magnetic fields, the time scale is also important. If the field medium has linear characteristics, then the pattern of the field does not depend on the magnitude of the field vectors.

Let the field-carrying medium be linear, and let the field vectors vary sinusoidally. Maxwell's equations of the electro-magnetic field are :

$$\text{curl } \dot{\mathbf{H}} = \Delta + j\,\epsilon\,\omega\,\dot{\mathbf{E}} \quad .. \quad .. \quad (1)$$

$$\text{curl } \dot{\mathbf{E}} = j\,\mu\,\omega\,\dot{\mathbf{H}} \quad .. \quad .. \quad (2)$$

$$\text{div } \dot{\mathbf{H}} = 0 \quad .. \quad .. \quad .. \quad (3)$$

$$\text{div } \dot{\mathbf{E}} = 0 \quad .. \quad .. \quad .. \quad (4)$$

Carrying out the operation curl on eq. (1), we obtain from eqs. (2) and (3) :

$$\Delta\,\dot{\mathbf{H}} = j\,\omega\,\mu\,\gamma\,\dot{\mathbf{H}} + \epsilon\,\mu\,\omega\,\dot{\mathbf{H}} \quad .. \quad (5)$$

Similarly from eqs. (2), (1) and (4) :

$$\Delta\,\dot{\mathbf{E}} = j\,\omega\,\mu\,\gamma\,\dot{\mathbf{E}} + \epsilon\,\mu\,\omega\,\dot{\mathbf{E}} \quad .. \quad .. \quad (6)$$

The Laplace operator can, without loss of generality, be expressed in Cartesian co-ordinates. Considering eq. (5) for the full-scale design and for the model, we demand that every quantity which enters into eq. (5) applied to the model, should, except for a scale factor $m$, be equal to the analogous full-scale quantity.

$$\left.\begin{array}{ll} \omega_m = m_\omega\,\omega_f\ ; & \gamma_m = m_\gamma\,\gamma_f \\ \mu_m = m_\mu\,\mu_f\ ; & \epsilon_m = m_\epsilon\,\epsilon_f \\ (\partial x_m)^2 = m_l^2\,(\partial x_f)^2\ ; & (\partial y_m)^2 = m_l^2\,(\partial y_f)^2 \\ & (\partial z_m)^2 = m_l^2\,(\partial z_f)^2 \end{array}\right\} \quad (7)$$

On this condition eq. (5) applied to the model becomes

$$\Delta\,\dot{\mathbf{H}} = j\,m_\omega\,m_\mu\,m_\gamma\,m_l^2\,\omega_f\,\mu_f\,\gamma_f\,\dot{\mathbf{H}} + m_\epsilon\,m_\mu\,(m_\omega)^2,\,(m_l)^2\,\epsilon_f\,\mu_f\,\omega_f^2\,\dot{\mathbf{H}} \quad (5')$$

and applied to the full-scale design

$$\Delta_f\,\dot{\mathbf{H}} = j\,\omega_f\,\mu_f\,\gamma_f\,\dot{\mathbf{H}} + \epsilon_f\,\mu_f\,\omega_f^2\,\dot{\mathbf{H}} \quad .. \quad (5'')$$

Obviously eqs. (5′) and (5″) will be identical if

$$m_\omega\,m_\mu\,m_\gamma\,(m_l)^2 = 1 \quad .. \quad .. \quad (8)$$

$$m_\epsilon\,(m_l)^2\,m_\mu\,(m_\omega)^2 = 1 \quad .. \quad .. \quad (9)$$

Multiplying eq. (8) by $\omega_f\,\mu_f\,\gamma_f\,l_f^2$, and considering eq. (7), we obtain the first criterion of similarity

$$l_m\sqrt{f_m\,\mu_m\,\gamma_m} = l_f\sqrt{f_f\,\mu_f\,\gamma_f} \quad .. \quad (10)$$

where $f = \omega/2\,\pi$.

Multiplying eq. (9) by $\omega_f^2\,\mu_f\,\epsilon_f\,l_f^2$, we obtain the second criterion of similarity

$$l_m f_m\sqrt{\epsilon_m\,\mu_m} = l_f f_f\sqrt{\epsilon_f\,\mu_f} \quad .. \quad (11)$$

We realise that $l_m = m_l\,l_f$ where $l_m$ and $l_f$ are the arbitrary but analogous dimensions representing the model and the full-scale design. It is customary to introduce eqs. (10) and (11) in the form

$$\Pi_1 = l\sqrt{f\,\mu\,\gamma} = \text{const} \quad .. \quad .. \quad (10')$$

$$\Pi_2 = lf\sqrt{\mu\,\epsilon} = \text{const} \quad .. \quad .. \quad (11')$$

It is easily seen that simultaneous observance of eqs. (10) and (11) is extremely difficult.

To ensure the constancy of both non-dimensional coefficients $\Pi_1$ and $\Pi_2$, it would be necessary to vary the magnetic permeability $\mu$. If the model is reduced to half its former size, $\mu$ must be increased by 4. Hence full model similarity with the same field-carrying medium is practically impossible.

It is customary to fulfil either eq. (10) or eq. (11). The choice is determined by the phenomenon which is being studied with the help of the model. If the conduction of currents is decisive, then the coefficient $\Pi_1$ must be maintained. If displacement currents in a dielectric medium are important, then the $\Pi_2$ criterion must be observed.

In electro-thermal installations it is convenient to scale only the dimensions and the frequency. The similarity criteria are then simplified into

$$\Pi_1 = l\sqrt{f} \quad .. \quad .. \quad (10'')$$

and $$\Pi_2 = lf \quad .. \quad .. \quad (11'')$$

where, naturally, either $\mu_m = \mu_f$, $\gamma_m = \gamma_f$, or $\epsilon_m = \epsilon_f$ are preserved.

Often, phenomena occurring in two different media simultaneously must be treated, e.g., in a conducting and a dielectric medium. Thus, in an induction furnace, current is conducted in the windings of the inductor and in the charge, while displacement currents exist between the windings of the inductor and in the walls of the crucible. All the same, in most cases the emphasis is on the investigation of current conduction (such as the heating of the charge or the casing, the action of protective screens, if any, electrical power efficiency, the power factor of the system inductor/charge). Therefore, when increasing the frequency to

reduce the size of the model in accordance with eq. (10″), we should not go too far if we wish to avoid distortion.

We must not deduce from eq. (11″) that the relation between the frequency and the magnitude of breakdown voltage in the inductors of vacuum furnaces can be found by experiments with a model. The criterion of high-frequency discharge in a gas under low pressure differs from that expressed by eq. (11″).

Let us consider a model to represent a large and complicated induction heating installation, designed for a frequency of 500 cps. The model frequency should not be outside the range of frequencies produced in mechanical generators. Let 8000 cps be our choice, for which standard generating equipment is normally available. The model is designed of such materials that $\gamma_m = \gamma_f$, $\epsilon_m = \epsilon_f$, and $\mu_m = \mu_f$. The linear dimensions of the model in accordance with eq. (10″) will be

$$l_m = l_f \sqrt{f_f/f_m} \quad .. \quad .. \quad (12)$$

We now proceed to choose the scale factor between $\dot{\mathbf{H}}_m$ and $\dot{\mathbf{H}}_f$, to fulfil the condition that the power absorption in the conducting elements of model and full-scale design should be the same. The losses in the conductors will be equal, provided that

$$\left( \int_{F_m} \mathbf{S}_m \, dF_m \right)_{\mathrm{R}} = \left( \int_{F_f} \mathbf{S}_f \, dF_f \right)_{\mathrm{R}} \quad .. \quad (13)$$

where $\mathbf{S}$ is the complex Poynting's vector, and $F$ is a representative full-scale or model area denoted by subscripts $f$ and $m$.

The integral equation (13), with similar magnetic fields, postulates the equality of the corresponding terms of the integral sum. Thus,

$$|\,\mathbf{H}_m\,|^2 \sqrt{f_m}\, \Delta F_m = |\,\mathbf{H}_f\,|^2 \sqrt{f_f}\, \Delta F_f \quad .. \quad (14)$$

if $\mathbf{H}_m$ and $\Delta F_m$ are the field vector and element of area determined in geometrically similar locations.

It follows from eq. (14) that

$$|\,\mathbf{H}_m\,| = |\,\mathbf{H}_f\,| \sqrt[4]{f_m/f_f} \quad .. \quad (15)$$

It is now possible to deduce the relation between the currents in full-scale design and model ; considering that the m.m.f. $\int \mathbf{H}\, dl$ is proportional to ampere-turns and that the numbers of turns are equal (geometric similarity)

$$I_m = I_f \sqrt[4]{f_m/f_f} \quad .. \quad .. \quad (16)$$

Equality of losses demands :

$$I_f^2 R_f = I_m^2 R_m \quad .. \quad .. \quad (17)$$

from which it follows that the relation between resistances is

$$R_m = R_f \sqrt{f_m/f_f} \quad .. \quad .. \quad (18)$$

Furthermore, with similarity of magnetic fields and observance of eq. (13), an equation for the imaginary part of Poynting's vector is also valid

$$(\mathbf{S}_f\, \Delta F_f)_{\mathrm{I}} = (\mathbf{S}_m\, \Delta F_m)_{\mathrm{I}} \quad .. \quad (19)$$

But the imaginary part of Poynting's vector is simply the flux of reactive energy. We therefore derive the following relation between the internal inductances by a train of thought exactly analogous to that which led to eq. (18)

$$(X_m)_i = (X_f)_i \sqrt{f_m/f_f} \quad .. \quad (20)$$

Subscript $i$ denotes the internal inductances linked with the magnetic fields in the conductors.

Let us now consider the relations between the external inductances. The external inductance (subscript $e$) is given by the following expression

$$w\, \Phi_e = I\, L_e \quad .. \quad .. \quad (21)$$

where

$$\Phi_e = Iw/(R_{\mathrm{mag}})_e = \mu_f\, Iw\, A_{\mathrm{mag}}/l_{\mathrm{mag}} \quad .. \quad (22)$$

is the magnetic permeability of vacuum and

$$l_{\mathrm{mag}}/A_{\mathrm{mag}} = \sum_{k=1}^{n} (l_{\mathrm{mag}})_k/(A_{\mathrm{mag}})_k \quad .. \quad (23)$$

where $k$ is the index number of an element of field space surrounding the metallic parts

$$(R_{\mathrm{mag}})_k = \frac{1}{\mu_f} \frac{(l_{\mathrm{mag}})_k}{(A_{\mathrm{mag}})_k} \quad .. \quad .. \quad (24)$$

defines the resistance of the element number $k$ of the external field space, to the passage of magnetic flux.

Eqs. (21) and (22) render

$$X_e = \frac{\omega\, \mu_f\, A_{\mathrm{mag}}\, w^2}{l_{\mathrm{mag}}} \quad .. \quad .. \quad .. \quad (25)$$

from which $(X_m)_e = (X_f)_e \sqrt{f_m/f_f}$ .. (26)

In short, the external reactances of the model and the full-scale design are related through the same scale factor as the internal reactances. Since the whole input reactance of the inductor is $X = X_e + X_i$, the power factors of model and full-scale design become

$$\cos \varphi_m = R_m/\sqrt{R_m^2 + X_m^2} \quad .. \quad (27)$$

$$\cos \varphi_f = R_f/\sqrt{R_f^2 + X_f^2} \quad .. \quad (28)$$

and, therefore, considering eqs. (18), (20) and (26), we conclude that

$$\cos \varphi_m = \cos \varphi_f \quad .. \quad .. \quad (29)$$

Equality of powers demands that

$$U_m I_m \cos \varphi_m = U_f I_f \cos \varphi_f$$

Considering eqs. (29) and (16) we have :

$$U_m = U_f \sqrt[4]{f_m/f_f} \quad .. \quad .. \quad (30)$$

Model testing proceeds as follows. When a steady temperature distribution is obtained, the losses imparted to the cooling water (inductor, housing cover) as well as the losses through the walls of the housing, and through the screens are measured by measuring the temperature distribution on the surface of the housing or screens. Deducting the power loss, from the power consumption measured electrically, the power absorbed by the charge can be found. Useful and wasted powers at experimental input voltages, different from those at nominal values, are related as follows

$$(U_{\mathrm{nom}}/U_{\mathrm{exp}})^2 = P_{\mathrm{nom}}/P_{\mathrm{exp}} \quad .. \quad (31)$$

Model techniques can also be used in the design of the secondary (input) power circuits feeding ore-refining and arc furnaces. The author is convinced that model techniques render better knowledge of the work of these circuits than actual measurements in practice. Most measurements carried out in industrial installations are subject to random errors caused by the conditions under which such measurements have to be conducted. The only correct method for measuring the impedance of each element of the installation separately would be to short-circuit one by one sections of the installation. This usually proves impossible in industrial conditions and it is common to attach measuring instruments at intermediate points. The author claims that this method does not give correct results even if voltages are measured by compensation methods.

Furthermore, it must be remembered that busbar installations work under very arduous conditions (high ambient temperature, flue gas atmosphere, high electric transients) and it is common to find large variations in contact resistance owing to corrosive phenomena. These changes of contact resistance are observed on some busbars and it is therefore difficult to obtain

characteristic data of an installation from measurements under operating conditions.

In the design of feeding circuits it is important to know to what extent they possess the following qualities : (1) minimum reactance and (2) minimum losses.

The author recommends for model tests a frequency of 2,500 cps. Since the full-scale frequency in this case is the mains frequency of 50 cycles, the linear scale factor becomes

$$m_l = \sqrt{f_m/f_f} \approx 7 \quad .. \quad .. \quad (32)$$

The general relations derived before on the scale factor for the active and reactive resistances are valid in this case and lead to the following equations

$$X_f = X_m \sqrt{f_f/f_m}\,; \; R_f = R_m \sqrt{f_f/f_m} \quad .. \quad (33)$$

HOLLAND

# An Indentation Meter for Paint

By J. HOEKSTRA and J. A. W. VAN LAAR. (From *Philips Technical Review*, Vol. 13, No. 12, June, 1952, pp. 352-359, 8 illustrations.)

THE hardness of a coating of paint is a measure of its resistance to damage in the form of indentations, scratches, etc. In the case of metals, the hardness is usually measured by the Brinell, Vickers or Rockwell test, and is determined as the ratio of the applied force to the area of an indentation produced by a round or tapered indentor of standard dimensions.

The application of these methods to coats of paint was, however, unsatisfactory because of the following reasons : (i) the impression is often not clearly defined, (ii) it is altered by the elastic recovery of the deformation, and (iii) it shrinks still further with time owing to the elasto-plastic flowing of the material (" retarded elasticity "). In addition, it has been found that the area of indentation in a coat of paint is not proportional to the applied load, so that a " hardness " indication is only complete if the load used is also specified.

## METHOD OF MEASUREMENT

To overcome the difficulties mentioned above, the following method of measurement was developed. A hard pointed ram, in the form of a regular square pyramid with an apex angle of 136 deg., is pressed with a suitable force against the surface to be tested. The depth of the impression is measured while the force is still being applied, and another measurement is taken after removal of the load to assess the relationship between the plastic and elastic parts of the deformation. The load used is also specified in each case. To obtain fully reproducible results, it is necessary in all tests to apply the force during the same period of time, and 30 seconds has been found suitable for most cases.

Most coats of paint have a thickness of not more than 25 to 100 microns. To obtain the true yielding of the outer surface, the penetration depth must therefore be limited to a few microns, and the measurement must be accurate to within 0·1 micron. An instrument was therefore developed to obtain an accuracy of this order, using an electrical zero method for the measurement of the depth penetration.

The instrument comprises a sapphire pyramid mounted on a ram capable of vertical movement. The ram carries, in a plane perpendicular to its main axis, the central plate of a differential capacitor, the two outer plates or electrodes of which are stationary. The capacitor is connected to a bridge arrangement, with two resistors of identical values in the other arms. An alternating voltage is applied across one diagonal and the output voltage from the other terminals is amplified and applied to an indicator. The bridge is balanced when the tip of the sapphire is at a certain level, i.e., when the centre plate of the capacitor is central between the two fixed plates.

The procedure is as follows :—(a) The paint is applied to a specimen plate. After drying, this plate is clamped to an adjustable platform on the instrument. (b) The bridge is balanced by setting the centre plate of the capacitor to its central position and compensating for any slight deviations. (c) The specimen is lowered until it just touches the tip of the sapphire. (d) A suitable force, for instance, 10 grams, is applied to the ram, thus forcing the sapphire into the coat of paint. (e) The specimen is quickly lowered by adjustment of the micrometer screw, until the centre plate of the capacitor is again central between the outer plates, thus cancelling the upward movement of the ram and re-

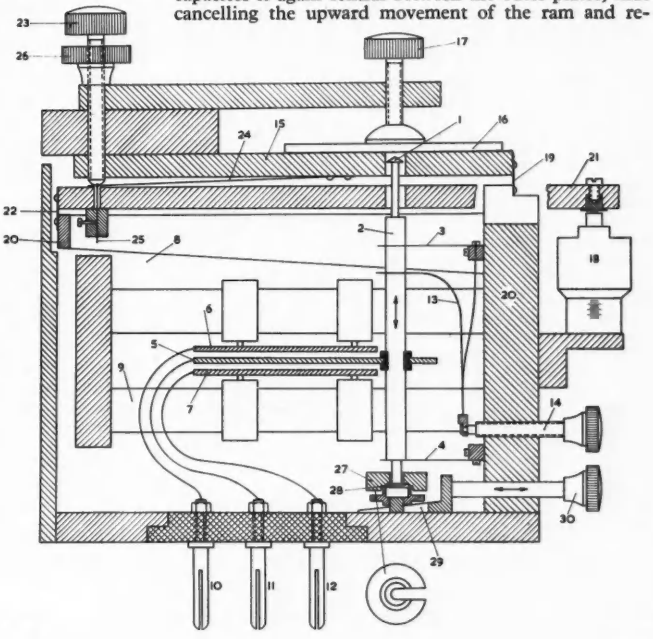



Fig. 1. **Sectional drawing of indentation meter.**

storing the load to exactly 10 grams. This downward pressure is maintained for 30 seconds, care being taken that the bridge remains exactly balanced. (f) The difference in micrometer readings taken at the stage (c) and at the end of the 30-second period then gives the penetration depth $i$. (g) If desired, after removal of the force at the end of the 30-second period, the bridge can be balanced again by readjustment of the micrometer screw, and a third reading is taken. The difference $\Delta i$ between the second and third readings then gives an indication of the elastic recovery of the paint tested.

## DESCRIPTION OF INSTRUMENT

A sectional drawing of the indentation meter is shown in Fig. 1. The sapphire (1) is mounted in a metal sleeve at the upper end of the ram (2), which is held in place by two flat springs (3) and (4). Attached to the ram, but insulated from it, is the movable plate (5) (approx. 4 × 5 cm) of the capacitor. The gaps on either side of this plate are only about 50 microns. The fixed capacitor plates (6) and (7) are rigidly supported by porcelain rods (8) and (9), cemented in place. As the ram is held in position by the two flat springs, movement of the centre plate is restricted to parallel displacement. Plug pins (10), (11) and (12) are for connection to the "Philiscope" bridge, which includes the resistance arms, an amplifier, a power unit, and a "magic eye" type balance indicator.

Positioning of the centre plate is by means of a thin steel wire (13), controlled by a screw (14), exact balancing being obtained by adjustment of the bridge resistors before the test. The specimen (16) is fixed to the platform (15) by means of a screw (17). The micrometer screw (18), in conjunction with the beam (21) and the adjustable screw (23), controls and indicates the height of the platform (15). The transmission of vertical displacement of micrometer screw (18) to platform (15) is obtained with a reduction of 50 : 1 with respect to the sapphire (1). The lengths $\{(20\text{-}25)/(20\text{-}18)\} \times \{[(19\text{-}2)/(19\text{-}23)\}$, where the numbers in this case refer to the centre lines of the corresponding items, are so arranged that the 50:1 reduction is obtained. Items (19), (22) and (24) are flat springs. Spring (24) is attached to beam (21) by a short piece of steel wire (25); (26) is a lock-nut and (27) a slotted ring-shaped weight of 10, 5, 2·5 or 1 gram. This weight rests on a shoulder (28) of the ram (2) and is lifted by a wedge (29) which is operated by means of a knob (30). When this knob is depressed, and the weights are lifted, springs (3), (4) and (13) can force the ram and sapphire upwards.

The minimum force with which the sapphire first comes into contact with the paint is 3 milligrams. This light pressure is obtained by using very flexible material for the flat springs (3) and (4). The initial load of 3 mg corresponds to a displacement before contact of 0·03 microns of the centre plate of the capacitor. Despite this high sensitivity, it has not been found necessary to take special steps to protect the instrument from vibration. It is probable that the air enclosed in the gaps between the capacitor plates has a damping effect. The overall accuracy depends mainly on the reproducibility of the micrometer adjustment and is within 0·1 micron. The limit in this case is set by the screw thread and the point of contact between the screw and the beam.

The instrument is of small dimensions and easily transportable. The sturdily-built framework is of aluminium alloy. The differential capacitor and other sensitive components are enclosed in a dust-proof housing. The use of the instrument does not require much routine.

## EXAMPLES OF TEST RESULTS

In the Vickers type test, the hardness $H$ [kg/mm²] is determined as the ratio of the applied load $P$ [grams] to the area $A$ [mm²] of the indentation. The lateral areas $A$ of a square-based pyramid of height $i$ [microns] and with an apex angle $\varphi = 136$ deg. is

$$A = i^2 \times 4 \tan(\varphi/2)/\cos(\varphi/2) = 26{\cdot}4\, i^2$$

so that the Vickers hardness is

$$H = P/A = 38\, P/i^2 \text{ [kg/mm}^2\text{]}$$

The hardness value is also included in the following table, although for paints it is necessary to indicate both the impression depth $i$ and the applied load $P$.

TABLE giving penetration depth and Vickers hardness of various paints tested with loads of 2·5 and 10 grams at 20° C. Load applied for 30 seconds.

| Type of paint | $i$ (microns) $P=2{\cdot}5$g | 10g | $H$ kg/mm² |
|---|---|---|---|
| Artists' paint | ⩾20 | ⩾20 | ⩽1 |
| Decorators' paint | >20 | >20 | <1 |
| Enamel for lighting fittings etc. | 4·5–3 | 9–6 | 5–10 |
| Synthetic paint for automobiles* | 6–3·5 | 14–7 | 2–8 |
| Nitro-synthetic paint for automobiles | 5–3 | 10–6 | 4–10 |
| Lacquer for radio cabinets | 4–3 | 7–5·5 | 8–12 |
| Cycle enamel (stoved) | 3–2·5 | 6–4·5 | 10–20 |

*Synthetic resin without nitro-cellulose.

Only those types of paint for which the $H$-value is below 5 kg/mm² are soft enough to be tested by scratching with the finger-nail. As shown in this table, many paints are too hard for testing in this manner.

*Influence of temperature:* For tests at various temperatures, the specimen plate was heated by a flat brass block provided with passages for hot circulating water supplied from a thermostatically controlled boiler. Two types of paint (white stoving enamel and white nitro-paint) were tested, with an applied load of 10 grams. The values obtained were as follows :—

| Temp. (°C): | 20 | 30 | 40 |
|---|---|---|---|
| | $i$ (microns) | | |
| Enamel | 5·6 | 7·6 | 9·5 |
| Nitro-paint | 6·8 | 9·4 | 13·8 |

It is thus recommended to carry out tests at a normal temperature, e.g., 20° C and to specify the temperature in the results.

*Effect of layer thickness:* It was found that the impression depth obtained with a given applied load increases as a function of the thickness of the layer. The curves of indentation depth against thickness of layer rise sharply at first and tend to become flatter for greater values of thickness. Moreover, the relative indentations for a given layer thickness are roughly proportional to the square root of the applied load.

The effect of layer thickness is important not only from the point of view of testing, but also in its application : A thin coat of paint is apparently more resistant to mechanical damage than a thick one, or, for the same resistance to damage, a thin coat of more plastic paint may be used. The thin film is also more economical and better able to follow the deformations of the underlying surface. It should be noted that as the thickness of the paint decreases, the apparent Vickers hardness of the paint more and more approximates the hardness value of the underlying material.

*Hardness variation during the drying process:* The tests, made on two types of air-drying paint, both containing $TiO_2$ as a pigment and identical volatiles, show a steep decrease in indentation depth during the first few days, with a much slower rate of decrease in the following periods.

Not only the ultimate hardness in the thoroughly dry state, but also the period required before the painted article can be safely handled are important factors. This "safe handling" condition may be said to be reached when the paint is resistant to scratching, that is, when it gives a penetration depth of 8·5 microns under a load of 10 grams, which corresponds to a "hardness value" of about 5 kg/mm².

# Simplified Design and Arrangement of Circuit-Breaker Equipment for the French Electricity Authority

By L. ALRAN, A. THIBAUDAT, C. BRESSON, M. GAY and A. VIBOUD. (From *Conférence Internationale des Grands Réseaux Electriques à Haute Tension*, May 28-June 7, 1952, Report No. 136, 29 pages, 9 illustrations).

## 1. GENERAL.

For a number of years European manufacturers of switchgear have tended towards the construction of small oil volume or air-blast instead of bulk oil circuit-breakers. The main reasons for this were the desire to reduce the cost price by reducing the weight of the equipment, and to decrease fire risk by using systems requiring only a small quantity of inflammable liquid or none at all. At the same time, unit control per pole has been adopted for all new circuit-breakers in view of the satisfactory results which had been obtained with breakers used for automatic reclosing. To avoid permanent dielectric stresses in the interrupting chamber when the switch is in the open position, automatically operating isolating switches are either made a part of, or are closely associated with, the circuit-breakers. As a result, the usual type of air blast or small oil volume circuit-breaker appears as an imposing assembly mounted on a heavy framework, and occupying a considerable amount of ground space. However, the active parts of circuit-breakers generally only represent a very small proportion of their total weight and cost.

It was with a view to reducing both the cost of production as well as the cost of installation that the French Electricity Authority requested the three largest switchgear manufacturers fundamentally to redesign their high and extra-high voltage switchgear and to produce new prototypes which would then be required to undergo stringent tests. The French Electricity Authority put at the disposal of these manufacturers the results of continuous technical observations to which the behaviour of all the circuit-breakers on their system had been subject since 1946. These had shown that the vast majority of the incidents which occur originates not in the interrupting system itself, but in the ancillary organs which are required for insulation, control, the transmission of mechanical movements, etc. It seemed, therefore, that continuity of operation could best be obtained by a separation of functions, i.e., by dividing the present complex breaker into independent sub-assemblies with only indispensable common functional points, and to reassemble these according to operational demands in a manner ensuring the maximum economy in installation and in operation.

On this general basis the three French switchgear manufacturers, Ateliers de Construction Électriques de Delle, Etablissements Merlin et Gérin and Forges et Ateliers de Construction Électriques de Jeumont, carried out an investigation into the modification of their conventional circuit-breakers, i.e., into an "orthojector" with straight contact travel, a small oil volume breaker with rotary contact travel, and an air-blast breaker respectively. These investigations led to outstanding designs by all three firms and, although only limited operational experience on these circuit-breakers is as yet available, their influence on the future development of switchgear practice cannot be overestimated. The following is a description of the three new designs, all of which provide for the overhead suspension of the circuit-breaker from transmission or substation structures by insulator strings.

## 2. THE NEW JEUMONT SMALL OIL VOLUME CIRCUIT-BREAKER.

Figure 1a shows the first alternative of the new design by Jeumont. The main contacts are placed, as in their conventional design, in the large porcelain insulator (a); however, the supporting structure has been replaced by the two insulator strings (b); a supplementary string (c) secures the breaker to the ground to prevent swinging in the wind. The live part (d) of the breaker contains the tripping springs, the closing lock and the closing mechanism.

A new oil-pneumatic control system was designed which will be used on the new, as well as on the conventional breakers made by this firm. It comprises a receiver filled with air pre-compressed to 250 kg/cm², and further compressed to 300 kg/cm² by a special oil pump driven by a small universal motor. The oil which only serves as a compressing medium is retained by a special valve. The actual operating mechanism consists of two pistons moving in opposite directions in a cylinder and actuating a rack and pinion arrangement. Tripping is effected by a spring.

The components of the oil-pneumatic control are either installed on the ground or on the gear. The jack and the tripping device, both of which are live, are

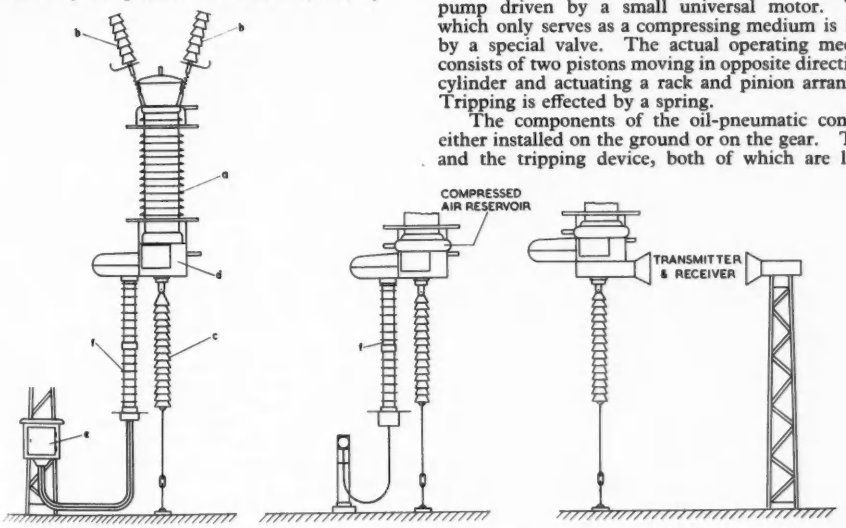



**Fig. 1a-1c. Three different arrangements of the Jeumont low oil content circuit-breaker.**

connected to the control mechanism (e) on the ground by small-section pipes. The insulation of these pipes is provided by the insulator (f) and by pieces of insulating tube. The control mounted at the foot of the pylon comprises the compressed air receiver with its pump, the electrically operated control valve and the control valve for tripping.

Fig. 1b shows a variation of the first design. In this the operating energy is supplied by compressed air at 200 kg/cm² carried in two cylinders (g) directly on the live part of the breaker. This is sufficient for about 500 operations. The control column (f) contains a simple mechanical device to transmit orders from two solenoids contained in a control box on its lower end. This box is at earth potential, and is connected to the general wiring by two flexible cables.

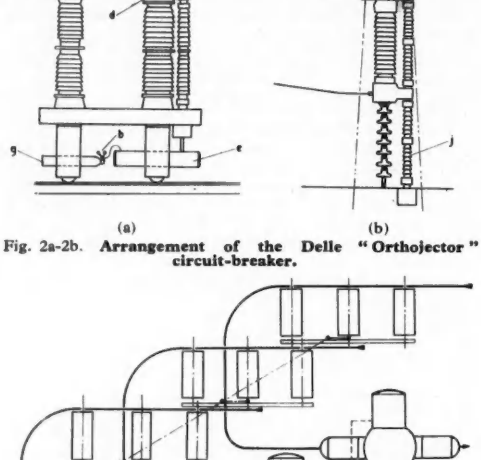



Fig. 2a-2b. **Arrangement of the Delle "Orthojector" circuit-breaker.**

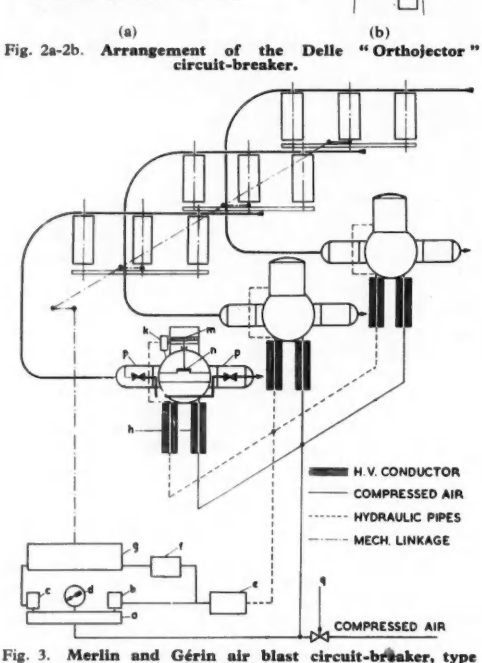



Fig. 3. **Merlin and Gérin air blast circuit-breaker, type PNS-8, 150 kV.**

(a) Air receiver; (b) tripping valve; (c) closing valve; (d) pressure gauge; (e) servo-motor; (f) damper; (g) air motor; (h) ceramic conduit; (k) servo-mechanism; (m) piston; (n) compressed air valve; (p) interrupting chamber; (q) non-return valve.

The operation of this circuit-breaker can be further simplified by providing two sensitive relays in the live control part operated by wireless control (Fig. 1c).

### 3. The New Small Oil Volume Circuit-Breaker of the A.C.E.D.

As can be seen from Fig. 2a, the principal interrupting organ comprises an oil-filled interrupting chamber (a) and a pneumatic operating mechanism (b), in which compressed air supplied through an insulating pipe (c) serves essentially for the closing operation. During this operation the tripping spring is compressed; on tripping, air is used only for tripping the spring. The isolating switch is operated by its own pneumatic control (d) which derives its air from the same source, i.e., a receiver (e) connected over a pressure-reducing valve (f) to a high pressure air bottle (g). Since compressed air is only used as a source of motive power, and not for quenching the arc, its consumption is very small and the contents of one high-pressure bottle is sufficient for a large number of operations.

In the new design (Fig. 2b) the isolating switch is separate from the main circuit-breaker, and is connected to it only by a compressed air pipe (g) which, at the same time, can be used as a conductor. It can be installed above the circuit-breaker on a separate base, thus reducing the ground space originally required. If the circuit-breaker, is not operated very frequently, the compressed air cylinders (h) can be mounted on the live part of the breaker, which can then be suspended from overhead structures by insulator strings (i). As, in this arrangement, the operating valves are alive, a small insulated mechanism (j) is provided for remote control of these valves. This mechanism can, in turn, be eliminated when remote control is effected by means of a short-wave wireless link.

### 4. The New Merlin and Gérin Air Blast Circuit-Breaker.

The principles upon which the design of this breaker was based are: (a) it is provided with a synchronised isolating switch, thus eliminating the need for one of the two isolating switches which, conventionally, are installed on each side of a circuit-breaker; (b) the compressed air receiver forms an integral part of the breaker, and is situated as near as possible to the main contacts, thus reducing the consumption of compressed air to a minimum; (c) the unit consisting of the air receiver and the two interrupting chambers can either be mounted on post-type insulators or suspended by insulator strings from overhead structures. Figure 3 schematically illustrates the operation of this circuit-breaker.

The electrical tripping signal opens valve (b), mounted on a small compressed air tank (a); in this way, air is admitted to the hydraulic servo-motor (e), setting the hydraulic control system under pressure, and thus transmitting the tripping impulse to the servo-mechanism (k) of each phase. This, in turn, admits compressed air from the main tank of the breaker to the piston (m), which, when rising, opens the main compressed air valve (n) of the breaker. Compressed air is thus admitted to the two ducts communicating with the two interrupting chambers (p). After an appropriate quantity of air has passed through the valve (n) and the interrupting chambers (p), piston (m) returns automatically to its original position and closes valve (n).

As will be seen from the diagram, valve (b) controls the admission of compressed air not only to the control mechanism of the circuit-breaker, but also to the operating mechanism of its synchronised isolating switches. This mechanism consists essentially of a time delay device acting on the air motor (g) which mechanically actuates the isolating switch. The delaying device is adjusted in such a manner that the isolator opens only when the break in the main circuit-breaker is completed. The isolators are closed by the actuating valve (c).

# Soviet Machine Tools

By J. MANNIN

IT was Benjamin Franklin who said that man can be defined as a tool-making animal. Few will dispute that there is some truth in the definition, but nowhere has it assumed a greater significance than in the Marxist philosophy and, not unnaturally, the proposition is honoured in the Soviet Union by an overwhelming respect for the " productive forces " in general and the machine tool industry in particular.

" A large machine tool-producing factory creates every year the equipment for six to eight engineering factories. Such an establishment is, therefore, in every sense of the word the factory of factories."

" One of the fundamental symptoms of the industrial development of a country, its economic independence and its power, is the saturation of its industry with metal-cutting machines."

Those are the words of an important Soviet official pronouncement dealing with the progress of the Russian machine tool industry. With more powerful authority, Mr. Stalin announced in 1932 " we had no machine tool industry ; we have it now." Clearly, the Soviet Union wishes to be judged on its performance in the field of machine tools. In this article an attempt is made to survey information which will contribute to such judgment.

The contents of this article can be summarised as follows :—

(1) Brief review of the history of machine tools in Russia, leading up to the present stage of machine tool production and utilisation.
(2) Outline of a catalogue of metal-cutting machine tools and allied equipment produced in the Soviet Union.
(3) Characteristic features of design and construction practised by the Russian machine tool industry.
(4) Description of technical advancements in Russian production techniques and mechanical equipment.
(5) Discussion of notable features in organising the operation of machine tools in Russia.
(6) Statistical review of the production and use of machine tools and allied equipment in the Soviet Union.

The survey of an industry can be inspired by at least one of two purposes. Either we wish to learn something *about* the industry or we are mainly concerned with learning *from* the industry. In this article we shall endeavour to deal with a little of each aspect. The information given will necessarily be brief and like many similar reviews, may appear to be arbitrary and superficial.

However, every effort has been made to include only such knowledge as is judged to be genuine. On a subject which can easily arouse political prejudice, this weeding-out of information requires a conscious effort, and no one, however well-meaning, can be sure of infallibility.

In the circumstances, it is fairer to reveal the sources and methods used. Machine tools and their accessories are practical things used by practical people. Few would suggest that practical men have a precise and infallible judgment. It is enough to notice their disagreements to be relieved of such notions. No honest shop-man will claim to be able to evaluate a machine tool to the last pound, but, having seen a lathe, " played about " with it and perhaps turned a piece or two, the practical shop-man will know its true value within a marginal error of ten per cent. The more formal and technically minded engineer, with his experience in the design and laboratory-testing of machine tools, will, with the aid of instruments, rules and specifications, complement the evaluation. Between them, the two men will form a very good idea of the engineering quality of a machine tool. This standard of judgment cannot be claimed in this article. It had to rely on printed information. All the sources used are Russian ; all, we are accustomed to think, are subject to more or less rigid censorship.

There is a school of thought which attributes a very low degree of veracity to Russian sources of information of any kind. This view can be challenged on more grounds than one, but, for those who bow to facts alone, this can be said. Firstly, in several instances the late War has afforded an opportunity of verifying Russian information. In these instances, it has been shown that the degree of truthfulness in Russian information does not compare unfavourably with that of other countries. To be precise, those who have learnt to read Russian sources and to make due allowance for expected prejudices have been able to extract estimates which have since been confirmed by facts.

Secondly, readers of engineering literature develop a healthy immunity to sales talk, and it is believed that these habits acquired in the commercial life of the West can be usefully applied in sifting genuine information from sales talk in the political sphere. In short, this article has been written in the belief that a large amount of genuine knowledge and information is published in the Russian technical literature.

## 1. HISTORICAL SKETCH.

The historical origins of the Russian machine tool industry are rooted in the cradle of Samovar manufacture, the town of Tula, during the reign of Peter the Great. Lathes were made by craftsmen engaged primarily in the manufacture of arms. The creations of these early forerunners show remarkable skill and inventiveness, but, like those of other countries, constitute no more than historical curiosities. Claims of priority, a current Russian obsession, need not concern us here. It appears that even such ultra-modern ideas as the introduction of rational sequences of numbers of revolutions and the realisation of the great benefits to be derived from interchangeability of components had their origin in the " prehistoric " period of machine tool manufacture.

In the second half of the nineteenth century the science of the metal-cutting process was taken up in Russia as in other countries, but, whatever the theoretical achievements recorded, the great revolution of mechanical production associated with the name of Taylor and the introduction of high-speed steel was left to the Americans, and pre-Revolutionary Russia became increasingly dependent on foreign developments and sources of supply, among which Germany took the first place.

Even the more rapid development of Russian industry in general which preceded the first World War was not accompanied by a commensurate rise in Russian machine tool production, the value of which in 1912 did not exceed 1 per cent of the output of the whole Russian engineering industry. At that time the annual production of machine tools reached about 1,500 machines. Taking into account the quality and complexity of the equipment produced, the situation was even less favourable. In 1918 there were only eight thread-grinding machines in the whole of Russia, and no more than sixteen broaching machines and 685 automatic lathes.

The first ten years following the Revolution did not witness a spectacular change, but the inauguration of the First Five-Year Plan was accompanied by the establishment of the Machine Tool Directorate at the Commissariat of National Economy (1928) as well as by other administrative measures. It is characteristic of Russian development that seats of learning devoted to the branch on which particular attention was focussed invariably marked the beginning of its forced development. In 1929 the first Chair of Machine Tool En-

gineering was created, and in 1930 a special institute for machine tool construction and a centre for technical tuition were opened in Moscow. Further institutes and organisations arose as follows :

1931 Scientific Research Institute for Machine Tools, Cutting Tools and Abrasives.
1932 Central Design Office and Test Laboratory for the Machine Tool Industry.
1933 Institute for Experimental Research in Machine Tools and Tools (ENIMS).
1935 Office for Standardisation in the Metal Industry.
1941 People's Commissariat for Machine Tool Construction in the Soviet Union.
1946 Ministry of Machine Tool Production.

The practical results of this development were truly spectacular. In 1932 nearly 20,000 machine tools were produced, and the number rose in 1941 to the figure given in the " 1941 Confidential Plan," namely, 58,000 machine tools of all types.

Whereas during the 1929-1931 crisis anyone working in a machine tool factory in the U.S.A., Great Britain or Germany could not have failed to notice long rows of machine tools with Russian labels, already during that period the Russian industry was copying most types of machine tools received from abroad. The next stage was characterised by the development of original designs symbolised by the slogan " Catch up and overtake." From there onwards an ever larger range of types was produced. In 1941 there were 450 different types in production. This brings us to the current period which will be discussed in subsequent sections.

## 2. Range of Soviet Machine Tools.

Centralisation of machine tool development was conducive to the introduction of a uniform classification of machine tools. The classification, organised in decimal form, is the basis of the Russian type numbers of machine tools. The first two numerals of the four-figure number are a reference to the classification, whereas the last two symbolise a size by which the type is characterised, such as height of centres in a lathe.

The Russian machine tool industry produces many types and sizes of machine tools in each of the eighty-odd categories into which they are divided by the system of classification shown in Table I. In short, the Russian machine tool industry has reached a stage where the limitations of its range can be more easily stated by enumerating those relatively few categories familiar to us wherein the Russian industry has not caught up with developments in the U.S.A. and elsewhere.

These gaps can be mainly characterised by large size of components and complexity of the cutting process. Thus, certain types of very heavy machine tools of all classes are repeatedly announced as newly completed constructions.

The gaps among copying and die-sinking milling machines have now been closed, but several types among the full range of gear-cutting and gear-finishing machines have not yet been produced in the Soviet Union. In 1948, Soviet engineers were admonished for their failure to employ the following production processes :—gear-shaving, diamond-boring, honing and flame hardening. The absence of the following machines was lamented :—gear-grinders with abrasive worm, centreless grinders with large working wheels, large-scale production of infinitely variable transmissions. Since then, several of these gaps have been filled, but it appears that some types, such as gear grinders on the MAAG principle, have not yet been reproduced.

At this point it is appropriate to mention that a few types of machine tools have been developed in Russia for which there are no precise equivalents in the West. Discussion of them will be left till Section 4, devoted to the pioneering achievements of Russian mechanical technology.

Table I.

1. Lathes
   1. Single-spindle automatics
   2. Multi-spindle automatics
   3. Capstan and turret lathes
   4. Centering and cutting-off lathes
   5. Vertical lathes
   6. Engine lathes
   7. Multi-tool lathes
   8. Specialised form cutting lathes
   9. Miscellaneous lathes
2. Drilling Machines and Boring Mills
   1. Vertical drilling machines
   2. Single-spindle semi-automatic drilling machines
   3. Multi-spindle semi-automatic drilling machines
   4. Jig borers
   5. Radial drilling machines
   6. Boring mills
   7. Diamond tool boring machines
   8. Horizontal drilling machines
   9. Miscellaneous drilling machines
3. Grinding and Polishing Machines
   1. Cylindrical grinding machines
   2. Internal grinding machines
   3. Fettling machines
   4. Special shaft grinding machines
   5. Fettling grinders
   6. Tool grinding machines
   7. Surface grinding machines
   8. Polishing machines
   9. Miscellaneous grinders
4. Compound Machine Tools
5. Gear-cutting and Thread-cutting Machines
   1. Spur gear shaping machines
   2. Bevel gear cutting machines
   3. Gear and spline shaft hobbing machines
   4. Worm wheel hobbing machines
   5. Gear chamfering machines
   6. Thread milling machines
   7. Gear finishing machines
   8. Gear and thread grinding machines
   9. Miscellaneous
6. Milling Machines
   1. Vertical milling machines
   2. Continuous milling machines
   3.
   4. Copying milling machines and die-sinking machines
   5. Vertical planer type milling machines
   6. Horizontal milling machines (planer-type)
   7. Universal milling machines
   8. Horizontal milling machines
   9. Miscellaneous
7. Planing, Slotting and Broaching Machines
   1. Openside planing machines
   2. Double-housing planing machines
   3. Shaping machines
   4. Slotting machines
   5. Horizontal broaching machines
   6.
   7. Vertical broaching machines
   8.
   9. Miscellaneous
8. Cutting-off Machines
   1. Lathe tool cutting machines
   2. Abrasive cutting machines
   3. Circular saw friction cutting machines
   4. Straightening and cutting-off machines
   5. Bandsaws
   6. Circular saws
   7. Hacksaws
   8.
   9.
9. Miscellaneous
   1. Machines for pipes and fittings
   2. Machines for sharpening of saws
   3. Centreless bar turning machines
   4.
   5. Machines for testing cutting tools

Centralised control and a large measure of centralised technical and scientific direction in the Russian machine tool industry may have some tendency to reduce the distinctions between individual plants and designing teams, but it would be wrong to conclude that these distinctions have been obliterated. The same centralisation also produces the counter-tendency to insist on specialisation, but beyond this distinction by product, the periodical trade press bristles with symptoms of individuality, frequently expressed with considerable force.

It will therefore be of interest to enumerate the plants producing the most important categories of machine tools and allied equipment. Such a list, though by no means comprehensive, will also give an idea of the geographical distribution of the industry.

| *Plant* | *Products* |
|---|---|
| **MOSCOW** | |
| Stankokonstruktzya | Gear hobbing machines, broaching machines, special lathes for pipe fittings, boring mill units, drill heads. Surface grinding machines, semi-automatic cylindrical grinders for ball races. |
| Stankonormal | Large hydraulic broaching machines, surface grinding machines mobile boring mills. |
| Krasnyi Proletaryi | Lathes, multi-tool semi-automatics, wheel lathes. |
| Sergey Ordjonikidse | Semi-automatics, multi-spindle bar automatics, machining lines. |
| Kaliber | Gauges and measuring instruments of all types, inspection plugs, ball sorting machines, dial indicators, etc. |
| Freser | Milling cutters, lathe tools, broaching needles. |
| MIS | Gauges, broaching needles, gear shaping tools, clinometers. Abrasives and grinding wheels of all types. |
| **LENINGRAD** | |
| Sverdlov | Planing machines, die-sinking machines, vertical lathes, copying lathes, boring mills (about 30 types). |
| Automat | Automatic lathes for wound stock. |
| Ilyitch | Tool grinding machines, fillet grinders for ball racers. |
| Krasnyi Instrumentalsticks | Special measuring instruments pneumatic gauges, gear inspection fixtures, automatic inspection machines. |
| Pnevmatika | Pneumatically-powered hand tools. |
| **GORKY** | |
| GSFS | All types of general and special milling machines. |
| **ODESSA** | |
| Lenin | Boring mills, diamond boring machines, honing machines. Radial drills. Thread grinding machines. |
| **KHARKOV** | |
| Molotov | Special grinding machines, cylindrical grinding machines, radial drills. |
| **KIEV** | |
| Gorky | Six-spindle semi-automatic lathes. |
| **MINSK** | |
| Kirov | Vertical broaching machines. |
| **GOMEL** | |
| Kirov | Slotting machines. |
| Proletaryi | Centreless grinding machines. |
| **STERLITAMAK** | |
| Lenin | Semi-automatic boring machines. Multi-spindle diamond tool boring machines. Deep boring machines, vertical honing machines. |
| **VORONEZH** | |
| Kalinin | Forging presses, forging hammers. |
| **KRAMATORSK** | Lathes for rolling mill rolls, cutting-off lathes. |
| **KUYBYSHEV** | |
| ZK | Thread milling machines. |
| **LUBNY** | |
| Kommunar | Lathes, capstan lathes. |
| **STARO-KRAMATORSK** | Forging presses, drop hammers, hand presses. |
| **TBILISSI** | |
| Kirov | Thread-cutting machines, pipe-threading machines. |
| **PENSA** | |
| Frunse | Single-spindle automatic screw cutting machines. |
| **TCHKALOV** | Shaping machines. |
| **SLOVGOROD** | Forging presses. |
| **DIMITROV** | Milling machines. |
| **ISHEVSK** | Lathes, capstan lathes. |
| **TCHELYABINSK** | Clock indicators. |

### 3. General Characteristics.

Comparison of machine tool structures and mechanisms of different origins outside the Soviet Union gives an overwhelming impression of far-reaching similarity. In this general picture, departures from common forms of construction and known mechanisms stand out as exceptions. Only in the more specialised categories of machine tools are individual designs conspicuous, but even there it would be difficult to discover features not common to exceptional machines of any one type.

The Soviet machine tool industry is no exception in this general pattern. Its machine tools in most categories closely follow established practice in their general conception, detail design, and even "architectural" appearance.

There is practically no example today of a Russian machine tool which could be said to constitute a true copy of an imported design, but in every category among the more universally used machine tools the designs of beds, guiding surfaces, gear boxes, driving motors and transmissions, spindles and spindle bearings, tool supports, chucking and collet attachments, and other details of the machines, bear a remarkable similarity throughout the world.

A few minor points may be mentioned. Perhaps the most important of all is the degree in which standardisation has been imposed on the Russian machine tool designer. This affects not only frequently recurring elements, like control organs, fastenings and others, but also a more rigid adherence to such aspects of standardisation as sequences of numbers of revolutions, sizes of components, gears, oil pumps, and others.

Some attempts are discernible to introduce standard sub-assemblies, such as gear boxes, drill heads, head stocks and others. In fact, in some reports on Russian machine tools this tendency is described as typical. Examination of existing designs does not support this view, and it seems that some observers are inclined to confuse the typical with the symbolic. The use of standard sub-assemblies is recognised in Russia as elsewhere as a desirable method of reducing the cost of machine tools, but there is little evidence that in the practical construction of the normal types of machine tools Russian designers have overcome the obstacles which face this method any more than designers in other countries.

This does not mean, of course, that such elements as drilling heads, milling attachments, gear boxes and other units, are not extensively used in the construction of *special* machine tools and specialised versions of normal machine tools. The ideal of a "Meccano" set of standard units, from which every type of machine tool can be "thrown together" with the minimum of time and effort and practically no development testing, has been accomplished in Russia in a number of cases. These "unit machines" constitute one of the novel departures in the Russian machine tool industry. They are often associated with the so-called automatic production lines. These designs will be discussed in Section 4, but quantitatively their use is exceptional rather than typical.

Among components found more frequently in Russian machine tools than elsewhere we note the electromagnetic clutch which is used in conjunction with electrically controlled automatic transmissions. As regards methods of fabrication, the great favour in which welding is held in the Soviet Union is not reflected in greater use of welded beds and frames of machine tools.

The impression conveyed by a study of the technical literature and incessant administrative exhortations is that economy in the use of skilled labour constitutes an overriding principle in the development of Russian production. In this, Russian industry is nearer to the

pattern of U.S. production than that of Western Europe. Moreover, scarcity of manual skill dictates a more thorough sub-division of labour into stages of training and official classification recognises a scale divided into ten classes. An example of this attitude is provided by a "sales talk" on the benefits of a die-sinking machine which can be operated by Class 2-4 Labour in the process of making dies, which formerly had to be manufactured by men classified under the 8-10 category of skill.

It appears that modernisation of existing machine tools is practised in Russia more often than in the West. Standard schemes of modernisation are issued by the Central Establishments of Machine Tool Technology if it is found that a relatively simple modification can give considerable gains in productivity. Thus, the widespread introduction of carbide-tipped tools after the last war was accompanied by a wave of modernisation which consisted simply in increasing the driving power of lathes and other machine tools. It was discovered that high-speed cutting could often be introduced in the higher range of existing spindle revolutions provided adequate power was available. In other cases, this modernisation had to be accompanied by exchanging gears in spindle transmissions.

Several typical features of Soviet methods are the direct result of chronic shortages. Soviet economy strives relentlessly after self-sufficiency, and once a material is declared as deficient in the national economy, a concentrated and persistent effort is made to reduce its consumption. In metal cutting, the hardest-felt deficiencies in Russia are those of tungsten and industrial diamonds. These shortages mainly affect the choice and design of cutting tools. Shortage of tungsten needed both for high-speed steels and tungsten carbide has led to much greater emphasis being placed in Russia on the design and production of tipped and built-up cutting tools, particularly milling cutters. Furthermore, it has been found that the amount of metal which can be removed with a unit of tungsten is considerably greater when the tungsten is used in a tungsten carbide tool than in a high-speed steel tool. The introduction of carbide-tipped tools is therefore urged by the need to save tungsten, even when no improvement in productivity can be achieved.

Shortage of industrial diamonds promotes efforts to perform the trueing and dressing of grinding wheels without the use of diamonds.

It is difficult to resist the temptation to regard the fundamental technical similarity of machine tools in Russia and other countries as a fact of some significance, though opinions may differ on its interpretation.

No one familiar with the current stage of Russian machine tool production will suspect a simple tendency for copying. Much less is it possible to deny the Russian's flair for originality. Many new ideas are put forward in periodicals and in patent literature. Studies have been devoted to the systematic and comprehensive review of technical possibilities. But in reduction to practice we usually find a return to familiar design. In short, they try to be different but cannot. Perhaps this signifies some measure of real wisdom in current designs.

## 4. Advanced Techniques in the Soviet Union.

An industry so vast and complex as the machine tool industry of a great industrial country, among which the Soviet Union must be counted today, advances on a broad front. The area of progress reaches from ideas to production models, and the value and significance of every novelty are not certain even if they could be easily recognised. This situation must be kept in mind when a review of the advances of the Soviet machine tool industry is presented. This review will here be sub-divided under several headings. Some advanced designs will be enumerated, which are judged to be on the level of the latest achievements elsewhere. A number of technical ideas will be mentioned which, even if to specialists they reveal nothing more than the writer's gaps in knowledge, are apt to illustrate the problems and technical thought current in the machine tool industry in Russia. Subjects of major scientific investigations will be listed together with the declared programmes of research institutions. Finally, some outstanding achievements of Russian mechanical technology will be discussed, in which she may perhaps claim to be leading the world.

It may be as well to state that in the more serious pronouncements of Russian specialists we find little of the inflated boasting, so much of which has recently appeared in the lay press. Occasionally, a little outburst aimed at "the shameless plagiarists of decadent American science" will increase the temperature of an otherwise sober study, but more authoritative is a statement published in February, 1948, that the Soviet machine tool industry has now decidedly entered the stage of creating original designs in all major categories. Again, in a leading article published in March, 1949, it is stated that "the Russian machine tool industry must persistently strive to create new types exceeding in technical standards, productivity, and operational qualities the best among the foreign models." The following lines will help readers to judge how far these more sober claims are justified.

Among advanced methods and designs, the most important and widespread are those summarised under the term of "speed machining." In fact, "speed man" has become a symbol in Russian production, much like the notorious Stakhanovite. Turners and milling machine operators become famous overnight for having reached some fabulous cutting speed in their work. As usual, the nonsense far exceeds the sense in this public ballyhoo, and what is said often means no more to the expert than stating the time of running a course without mentioning its length. As every tool engineer knows, cutting speed means nothing without at least the knowledge of the cross-section of the cut and the life of the tool between re-grinds. We can therefore ignore the meaningless boast that Russian turners had reached a cutting speed of 7,000 fpm at a time when their American "Tovarishchi" were creeping along at 2,000 fpm. In competent terms, the new era of high cutting speeds inaugurated mainly by the introduction of carbide tools, and other discoveries, can be characterised as follows :—

In the fine machining of medium steels, a speed of 2200 fpm can be achieved. With $\frac{1}{8}$ in.-$\frac{1}{4}$ in. depth of cut and 12-30 thou. advance per rev., the range of speeds is 300-1000 fpm. In semi-automatic chucking lathes and automatic screw cutting lathes, cutting speeds of 120-300 fpm cannot be exceeded. Fine cuts in hardened steel (above 450 Brinell) can be taken at 190 fpm. Cast iron speeds of 220-550 fpm are common. Austenitic steels can be cut successfully at speeds ranging between 450 and 800 fpm, and non-ferrous metals allow practical machining at speeds up to 6500 fpm.

These figures are the ranges taken from practical recommendations issued with official support. On the whole, they are advanced but not outstanding and embody a tendency of modern cutting processes, confirmed in all industrial countries. This tendency arises from the realisation that carbide-tipped tools in combination with negative rake geometry give good, if not better, productivity and adequate tool life with very high speeds and small cross-sections of cut. It is recognised in Russian sources that much of the gain is due not to the speed itself but to the ability of using simpler machines and tools than would be required if the capacity of carbide cutting edges were used to the full at slower speeds and deeper cuts.

*To be continued.*

# The Influence of Sound and Ultrasound on Electro-Chemical Processes

By A. ROLL. (From *Metalloberfläche*, Vol. 4, Nos. 4, 5 and 6, 1952, pp. B49-53, B65-70, and 81-89 respectively, 26 illustrations.)

## PART I.

A knowledge of the physical basis of sound and ultrasound phenomena is essential for a correct evaluation of their influence on electro-chemical processes, especially in view of the fact that technical electro-chemistry is still to a large extent an empirical science. The physics of ultrasound will be discussed in the first part of this article. For further information, the study of specialist literature is recommended[1].

### A. THE PHYSICAL DETERMINING FACTORS OF SOUND AND ULTRASOUND.

By sound or ultrasound is understood the elastic vibrations of a medium. The distinction between the two is somewhat arbitrary, based on the upper limit of audibility, which is conventionally taken to be 10 kcs. Apart from the frequency $f$ (or angular frequency $\omega = 2\pi f$) and the sound velocity $v$, there are a number of other quantities describing the elastic vibrations, which will be introduced below.

1. *The motion of single particles in a sound field (amplitude of oscillation).*

When sound is propagated in an elastic medium, each particle performs an oscillation about its rest-position with the frequency of the sound, and in the direction of propagation. The phase of oscillation of the particles varies along the direction of propagation (see Fig. 1a). The shortest distance along this direction between two planes in which the particles are in phase is the wavelength $\lambda$.

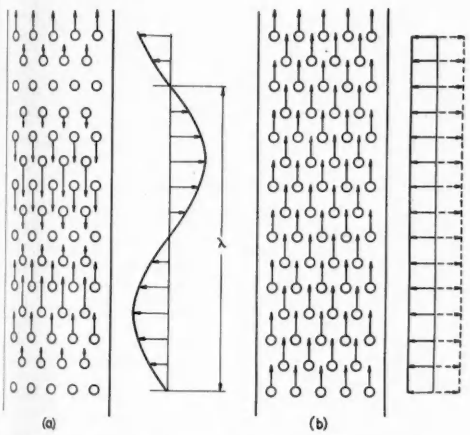



Fig. 1. **Oscillation of particles in an elastic medium.**

It may happen, when using sound of low frequency (long wavelength), that all the particles of a short object vibrate in phase with the exciting frequency. In this case there exist no elastic vibrations, but merely the oscillation of the object as a whole (Fig. 1b), and therefore no specific sound effects can be expected.

The amplitude of oscillation of a particle, parallel to the direction of sound propagation, is given by

$$A = \frac{1}{\omega}\sqrt{\frac{2I}{\rho v}} \quad .. \quad .. \quad (1)$$

where $\rho$ = density of medium, and $I$ = intensity of sound. At an intensity of 1 watt/cm² the maximum amplitude in water is 36$\mu$ at 500 kcs, and 0·18 mm at 100 kcs.

2. *Sound intensity.*

This is defined as the sound energy passing per second through unit area normal to the direction of propagation. It is difficult to measure directly, and is usually established from calorimetric or sound pressure measurements. Local energy densities of 100 watt/cm² can today be reached with high-frequency ultrasound (for comparison, intensity of sound from firing an artillery gun in air is 10 watt/cm²). Sound intensities of this order of magnitude may be expected to have special effects.

3. *Sound radiation pressure.*

The radiation pressure due to a progressive sound wave is given by

$$S = \frac{I}{v} \quad .. \quad .. \quad .. \quad (2)$$

If the wave is reflected, the reflecting wall experiences a reaction, which assumes twice the above value of the pressure when standing waves are formed. The pressure in water for an intensity of 1 watt/cm² is 70 mg/cm², i.e., it is readily measurable. Particles suspended in a liquid are propelled forward owing to this pressure.

4. *Pressure changes in the medium.*

Sound is propagated by a compression wave and, in liquids, considerable local pressures may arise on account of the low compressibility. The maximum local pressure may be calculated from

$$P = \sqrt{2I\rho v} \quad .. \quad .. \quad (3)$$

Owing to rapid local alternation of tension and compression, the large forces present may, at high sound intensities (1-2 watt/cm²), cause cavitation. Research has shown that cavitation is dependent on the presence of gas nuclei.

Cavitation is responsible for a number of effects. For instance, liquids are degassed; during electrolysis the liberated gases are sucked up by the cavities; owing to adiabatic processes during the formation and collapse of gas bubbles very high local temperatures may arise[2], resulting in secondary effects.

5. *Maximum particle velocity.*

The maximum velocity of a particle oscillating about its mean position is given by

$$U = \sqrt{\frac{2I}{\rho v}} = \omega A \quad .. \quad .. \quad (4)$$

It is independent of frequency, and is small in comparison with the velocity of thermal vibrations of the particle.

If an electrolyte contains ions of different masses, they will be excited to oscillation, depending on the relative velocity and mass of the ions, the heavy ones "lagging behind." This phenomenon can be used for determining the mass of the ion[3].

6. *Particle acceleration.*

The maximum particle acceleration is

$$B = \omega\sqrt{\frac{2I}{\rho v}} \quad .. \quad .. \quad (5)$$

and is a function of the frequency. It can reach very high values, e.g., at a sound intensity of 1 watt/cm² in water, it reaches 715 g at 10 kcs, and 36,000 g at 500 kcs.

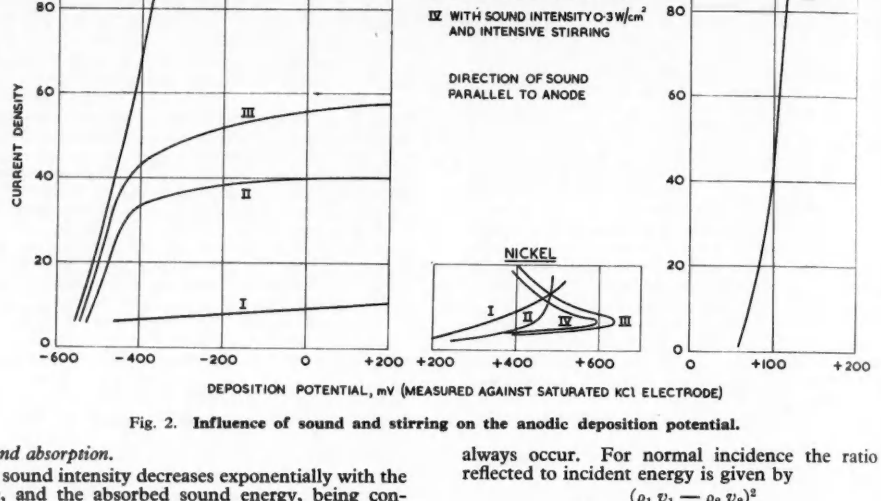

SILVER
mA/cm²
CURRENT DENSITY
I WITHOUT SOUND OR STIRRING
II WITH INTENSIVE STIRRING
III WITH SOUND INTENSITY 0·3 W/cm²
IV WITH SOUND INTENSITY 0·3 W/cm² AND INTENSIVE STIRRING
DIRECTION OF SOUND PARALLEL TO ANODE
NICKEL
COPPER
DEPOSITION POTENTIAL, mV (MEASURED AGAINST SATURATED KCl ELECTRODE)

Fig. 2. **Influence of sound and stirring on the anodic deposition potential.**

7. *Sound absorption.*

The sound intensity decreases exponentially with the distance, and the absorbed sound energy, being converted into heat, can cause a considerable increase in the temperature of the medium.

Sound and ultrasound are normally produced piezoelectrically (quartz, Rochelle salt, barium titanate) or by means of magnetostriction (nickel, Ni-Fe alloy). The exciting frequencies are produced mechanically or electronically. For frequencies below 10 kcs, the vibration amplitude of the generating surface can be measured directly under a microscope, and hence the intensity can be calculated. It is usually assumed that the amplitude of the generating membrane is imparted to the neighbouring medium without loss. Equation (1), however, is only valid for very high frequencies, while for lower frequencies the following formula must be used :

$$I = \frac{1}{2} A^2 \omega^2 \rho v \left(\frac{\pi r_0}{\lambda}\right)^2 \quad .. \quad .. \quad (6)$$

here $r_0$ = radius of radiating surface, $\lambda$ = wavelength in the medium. This equation holds as long as $2\pi r_0 < \lambda$; for shorter wavelengths eq. (1) is valid.

Thus, the intensity is reduced by a factor dependent on the ratio of membrane circumference to wavelength. This fact is especially important in the generation of very low-frequency sound, when an appreciable intensity is required.

A further consideration is the dependence of the angular intensity distribution on the relation between wavelength and diameter of radiating surface. The angular aperture $\varphi$ of the radiated beam is given by

$$\sin \varphi = 1{\cdot}22 \frac{\lambda}{d} \quad .. \quad .. \quad .. \quad (7)$$

i.e., the beam is more nearly parallel for small wavelengths and a large radiating area. For long waves the radiation is practically spherical and, therefore, the intensity in any direction is small.

Since the intensity usually increases with frequency, it is often difficult to decide whether an apparent frequency-dependence of an observation is real or is, in fact, merely due to the higher intensity. This difficulty is increased owing to the lack of accuracy of indirect intensity measurements.

In experiments with sound, reflections at interfaces always occur. For normal incidence the ratio $R$ of reflected to incident energy is given by

$$R = \frac{(\rho_1 v_1 - \rho_2 v_2)^2}{(\rho_1 v_1 + \rho_2 v_2)^2} \quad .. \quad .. \quad (8)$$

where $\rho_1$ and $\rho_2$ are the densities, and $v_1$ and $v_2$ the sound velocities in the respective media. Thus, reflection is greatest when the product $\rho v$ (sound resistance) of the two media differs greatly.

The " transparency " to sound of a plate is greatest when its thickness is an integer multiple of half a wavelength, and smallest when it is an odd multiple of one quarter of a wavelength. This factor must be considered when, as is customary, sound enters the reaction vessel through its base, and attenuation is to be avoided.

B. The Effect of Ultrasound on the Passivity of Metals.

1. *Passivity in the currentless state.*

It is known from experiments that ultrasound has a strongly dispersive effect at the phase boundaries. Low-melting point metals can be dispersed in water at very high sound intensities[4], and a true colloidal solution results. It seems that the mechanically passive surface is removed by the action of ultrasound.

In one experiment the behaviour of pure iron in concentrated sulphuric acid was investigated[5]. Without ultrasound the initial hydrogen evolution ceased after about 10 minutes. On the application of ultrasound, the hydrogen continued to develop and the solution gradually became clouded. On removing the ultrasonic field, the iron became passive again within 10 minutes. The explanation must be that the application of high-intensity sound mechanically removed the surface layer and allowed the acid to penetrate to the pure metal.

The effect of concentrated nitric acid on iron and chromium is an example of chemical passivity. Without ultrasound, an iron plate immersed in the acid becomes passive after a few seconds. In an ultrasonic field, however, gases continue to develop and the iron goes into solution. Already passive iron becomes active again in the ultrasonic field. On removing the sound field, the iron does not become passive again, even if it is rinsed with water and put into fresh acid.

The very much higher passivity of chromium in nitric acid could not be removed by application of ultrasound except in one experiment which could not be reproduced. Apparently, exceptionally high sound

intensities are required, which were produced by focussing the sound in a funnel-shaped vessel.

The experiments show that chemical as well as mechanical surface passivity is influenced by ultrasound. This behaviour may be explained by the assumption that the high-intensity sound disperses the neutralised surface layers, thereby exposing the active centres below to the action of the acid. Another explanation of increased chemical activity is the change of deposition potential of the gas generated. This point will be further discussed below.

2. *Passivity at a polarised anode.*

Investigations were also carried out on the influence of ultrasound on anode polarisation. As an example, the behaviour of a lead anode in a saturated solution of sodium carbonate was tested. At a constant current density the potential at the anode changes from initially negative values to positive ones and remains constant on reaching the oxygen evolution potential, after which only oxygen is evolved. Under the influence of ultrasound this process is slowed down. This can also be achieved by intensive stirring. By this means, reaching of the oxygen evolution potential may be delayed by several hours, as compared with 12 minutes in the normal case. The effect of ultrasound and of stirring cannot be distinguished and must evidently be the disturbance of the surface layer.

It is usually assumed that an iron anode in dilute caustic soda becomes passive owing to the formation of an oxide film. The formation of such a film may be expected to be disturbed by ultrasound. This, however, is not the case, as was established in a number of experiments. It would appear, therefore, that the passivity here is not a pure surface effect. It was even found that at sufficiently high sound intensity the activating effect of chlorine ions is stopped.

An effect contrary to lead is shown by the influence of ultrasound on aluminium in a 0·4 N solution of sodium sulphate. Here, polarisation is accelerated. The aluminium oxide film which adheres strongly is probably still removed initially by the ultrasound. However, under the action of oxygen which is simultaneously evolved, the surface oxide film is rapidly re-formed. The formation of thick surface layers is nevertheless still prevented by the ultrasound, as the potential is kept at a lower value than is the case with normal polarisation.

The above results on the passivity of metals in the presence and absence of current may be looked at from another angle. In one case the stirring has the same effect, if not so pronounced, as the ultrasound. It may be assumed with great probability that in this case the ultrasound simply produces a more intensive stirring effect than can be produced by other means. In the other case, when intensities above 1 watt/cm² are used, cavitation effects begin to play a part, attacking the surface mechanically.

In another set of experiments, carried out by the author, the behaviour of silver, nickel and copper anodes was investigated[6]. The experiments were carried out at a frequency of 34 kcs, and a maximum sound intensity of 0·3 watt/cm². Also, the direction of the sound was parallel with the anode, while in the work described earlier the sound beam was normal to the anode surfaces.

Fig. 2 shows the dependence of the anode deposition potential on the current density. The deposition potential of copper, which does not become inactive, is not measurably affected by stirring and ultrasound. The passivity of nickel is increased by the same means, up to a certain value of the current density. The effect of sound is to reduce the passivity again, possibly through a mechanical disruption of the inactive surface layer. Both the graphs for nickel and silver show that that action of sound and stirring is similar.

Summarising, it can be said that no uniform picture of the influence of ultrasound on surface passivity has been obtained. The mechanical passivity may be increased or decreased, and the same applies to chemical passivity. The application of ultrasound to the investigation of surface activity does not yield new and precise data on this problem. It is possible, however, to compare the effect of low-intensity ultrasound with that of stirring, both having the same qualitative effects. High-intensity sound presumably damages or destroys the inactive surface layers by cavitation.

## PART II.

### C. Electrolytic evolution of gases under the influence of ultrasound.

Extensive investigations in this field have been made by G. Schmid and L. Ehret[7]. A considerable effect of ultrasound on gas evolution is to be expected, and according to a French patent[8] it is even possible to precipitate aluminium and magnesium from dilute solutions by altering the deposition potentials by means of ultrasound. While nothing is known of the practical realisation of this patent at the present time, the following simple experiment, described by the above authors, shows the effect of ultrasound on the separation processes at the cathode: on electrolysing a fairly acid solution of nickel sulphate (pH = 2·1) employing a copper cathode and small current density (4 mA/cm²), no separation of nickel occurs. If the experiment is repeated in a moderately intense ultrasound field, a uniform deposit of nickel is obtained. By means of ultrasound, electrochemical processes can thus be guided in a different direction.

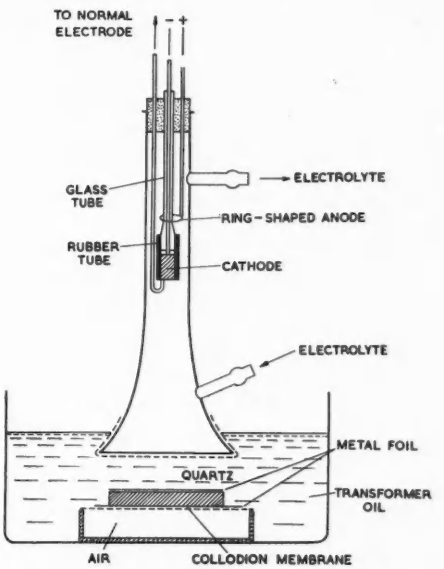



Fig. 3. **Apparatus for electrolytic experiments with a sound-concentrating vessel.**

Static potentials are not appreciably affected by ultrasound, while gas evolution potentials are remarkably strongly influenced. Fig. 3 shows the apparatus of G. Schmid and L. Ehret, used for the measurement of these potentials. The total radiated energy is 200W, requiring a high-frequency generator of 1kW output. The funnel-shaped glass vessel, enclosed below by a collodion membrane, serves to concentrate the sound beam over a small area. The cathode, a metal cylinder of 10 mm diameter, is placed in the position of maximum sound intensity. The potential was measured by a KCl contact point applied to the cathode and connected to a

normal electrode. The electrolyte was kept in continuous circulation and was cooled. The sound intensity could be varied either by altering the potential applied to the quartz, or by altering the quartz—cathode distance. The maximum intensity concentration at the cathode occurs when this distance is a multiple of half a wavelength (taking into account the different wavelengths in the oil and in the electrolyte). The optimum position is simply achieved by listening for the characteristic hissing noise caused by cavitation. At the cathode, the cavities were radially, but sometimes randomly, distributed.

Fig. 4 shows the dependence of the cathode potential for a given current, on the quartz—cathode distance, for a nickel electrolyte. The potential depends very strongly on the position of the cathode. At certain points where the hissing noise of cavitation is also observed, the potential is considerably reduced. These potential minima are separated by a distance which is exactly the semi-wavelength of the sound in oil. After being exposed to ultrasound, the nickel-plated cathode showed a dark purple pattern, but otherwise behaved normally with regard to the development of a potential.

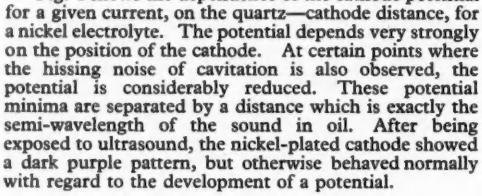



Fig. 4. **The dependence of ultrasound-depolarisation on the quartz—cathode distance.**

$J_s$ = H.F. current as a measure of sound intensity.

For comparison, the potentials for an undisturbed and a strongly stirred electrolyte are also shown in Fig. 4. The maximum depolarisation due to ultrasound exceeds by 3 to 400 mV that due to stirring. For the values lying between the two potentials we may speak of a polarising effect of the ultrasound with respect to the potential with stirring, and a depolarising effect with respect to the potential without stirring. Fig. 4 shows that these effects are to be expected only at high sound

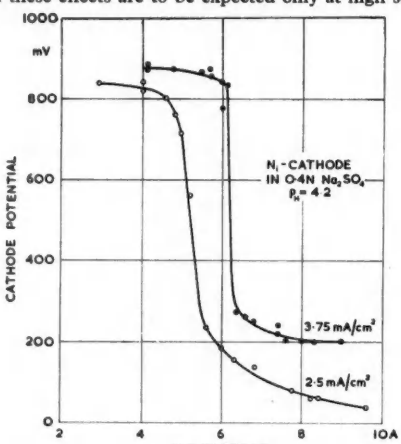



Fig. 5. **Graph showing the relationship between cathode potential and sound intensity.**

intensities. At lower intensities, the influence of the cathode position is small.

The relation between sound intensity and cathode potential is shown in Fig. 5 for different current densities. The intensity is measured in terms of the H.F. current applied to the quartz oscillator. Up to a certain intensity the potentials are stable. In the transition region they sometimes vary by as much as 100 mV during measurement. At high intensities, once more stable values are reached. The results were reproducible within a few mV, provided the experimental set-up was undisturbed.

Further experiments indicated that the nickel content of the electrolyte was without influence on the depolarisation effect, while the height of the potential jump depends on the pH value. It may be concluded that only the hydrogen evolution is responsible for the effect observed. Further experiments on a nickel-free electrolyte in a solution of sodium sulphate, acidified to different pH values with citric acid, gave the following results :

(a) Depolarisation always sets in at about the same sound intensity, independent of the current density. The hissing noise of cavitation appears at the same time

(b) The lower the current density, the steeper the jump in potential. Above a certain current density, no jump at all was observed.

(c) The height of the depolarisation jump is almost independent of the current density.

(d) The evolution potential of hydrogen can be depressed below the reversible equilibrium potential by means of ultrasound. Fig. 6 shows the potentials for a strongly stirred and a sound-irradiated electrolyte, as a function of current density. The ultrasound curve runs near to the reversible potential and, at low current densities, it falls considerably below it. Above 10 mA/cm² the ultrasound curve breaks off, as the available sound intensity here is insufficient to bring about the depolarisation jump.

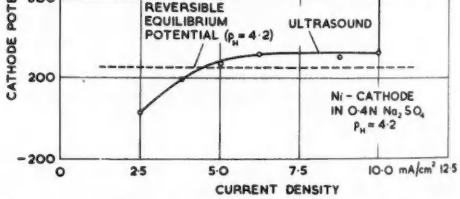



Fig. 6. **Dependence of cathode potentials on current density.**

(e) The influence of the material of the cathode on the height of the jump was investigated in neutral sodium sulphate solution at 2·5 mA/cm² current density. All the metals employed gave a fairly uniform jump of an average of about 820 mV, with the exception of platinum and magnesium. For platinum, the value was 500 mV. As the over-voltage of hydrogen with respect to platinum is only reached very slowly, this may cause too low a result. Magnesium, however, shows an entirely different behaviour in that in place of depolarisation a noticeable polarisation occurs with increasing sound intensity. For low intensities, most metals show a small amount of polarisation, which may be explained by the change of the metal surface in the ultrasonic field.

(f) The ultrasound potential is practically independent of the pH value of the electrolyte. As the potential increases with increasing pH, the potential jumps also increase with increasing pH, as the experiments showed.

The above observations on the processes occurring

(*Continued on page* 244)

# Electrical Contact Resistance between Metallic Surfaces Subjected to Various Treatments

By T. FUKUROI and Y. MUTO. (From *Science Reports of the Research Institutes, Tôhoku University*, Series A, Vol. 3, No. 3, June, 1951, pp. 281-291, 7 illustrations.)

THE work of Holm and his collaborators showed that contact resistance consists of two parts, viz., convergence resistance and transition resistance. The convergence resistance is attributed to the contraction of the streamlines of current through a small contact area. The transition resistance occurs in the outermost layer of the metal surface, and is attributed to the presence of adsorbed gas films or oxidised layers on the metallic surface. These layers act as a potential barrier through which the electrons can only pass because of the tunnel effect. Transition resistance is practically independent of temperature.

The following lines describe further experiments on the contact resistance of metals subjected to various surface treatments.

## TEST APPARATUS AND PROCEDURE

The circuit arrangement used is shown in Fig. 1. The tungsten rods investigated in the tests were pressed together crosswise at right angles. Each rod was connected at one end to a current terminal and at the other to a potential terminal. The potential difference at the contact and the current across the contact were measured by means of a potentiometer, the contact resistance being obtained as the ratio of these two values. To cover the wide range of resistance values corresponding to different surface conditions, a standard resistance of 0·1, 0·01 or 0·001 ohms was included in the circuit.

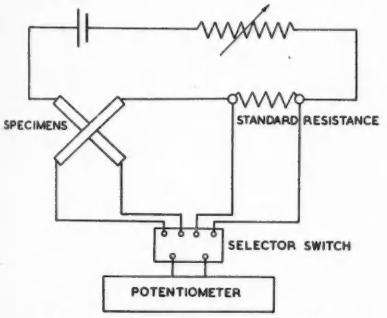



Fig. 1. **Measuring circuit for contact resistance.**

A schematic drawing of the measuring apparatus is shown in Fig. 2. Loads ranging from 10 to 100 grams were applied to the contact points by means of the spring force of a piano wire, the tensile strain of which was determined with the aid of a cathetometer. To obtain contact pressure, one tungsten rod was secured in the lower part of the inner glass cylinder I and the other rod was pulled by the spring force previously mentioned. The temperature was varied by means of a constantan heater *H*, from the boiling point of liquid air up to room temperature. A copper-constantan thermocouple, firmly attached to the specimen, was used for temperature measurements. The entire apparatus was placed in a glass cylinder *O*, closed at its lower end, and hydrogen gas was introduced to protect the contact surface from congealment of water when the cylinder *O* was immersed in liquid air.

To obtain similar contact conditions in all the tests, the fixed specimen was subjected to small-amplitude mechanical vibrations at one end, before each test. This increased the contact area to a fairly constant value and served to remove to some extent the extraneous layer at the contact.

The tungsten specimens used were 2 mm in diameter and about 5 cm long. They were subjected to three different surface treatments: (a) mechanical polishing with fine-grade emery paper, (b) electrolytic polishing, carried out in a bath made of a 50 per cent caustic soda solution, and (c) electrolytic etching, using the specimen as the anode and a carbon rod as the cathode, with a current density of 4-5 A/cm² and a potential difference of 6-8 volts. By immersing the specimen for about half a minute, a fine and glossy surface was obtained.

Electrolytic etching was also carried out in a similar solution with a p.d. of 1·5-1·7 volts and a current density of 3 A/cm² for about 20 seconds, which gave a fine micro-crystalline structure. To obtain uniform surface conditions, it was necessary to use new solutions for each treatment, since the properties of an electrolyte are affected by its previous history. After the surface treatment, the specimen was washed in pure alcohol and the contact resistance measured immediately. It was found that when benzol was used for rinsing, the surface appeared to be coated with a thin film resulting in very high resistance values.

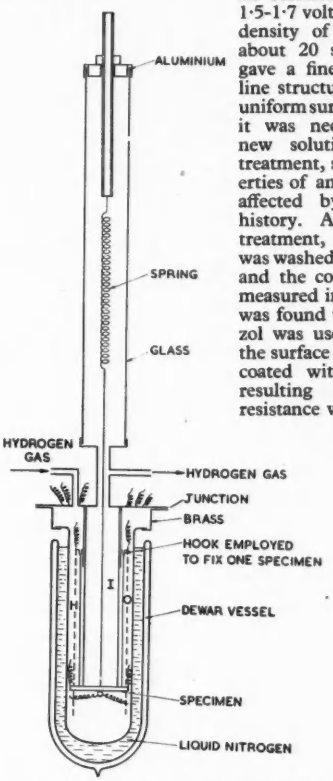



Fig. 2. **Schematic drawing of apparatus used for measuring electrical contact resistance.**

## EXPERIMENTAL RESULTS

*Influence of time of contact:* The initially high contact resistance decreases with time following a hyperbolic law. Typical values are given in the following table.

| Time (min) | 2 | 5 | 10 | 30 | 50 | 80 | Specimen |
|---|---|---|---|---|---|---|---|
| Load | Contact resistance (ohms) | | | | | | |
| 50 gr | — | 1·2 | 1·0 | 0·70 | 0·62 | 0·52 | A |
| 100 „ | — | — | 0·35 | 0·017 | 0·12 | 0·11 | B |
| 100 „ | 0·23 | 0·075 | 0·043 | 0·021 | 0·013 | — | C |

*Effect of applied load:* The tests showed that the contact resistance decreases with increasing loads. The average values of contact resistance $R$ (in ohms) as a function of the applied load $P$ (in grams) can be represented by the following formulae :—

$$R_{(e.p.)} = 0{\cdot}34\ P^{-1}; \quad R_{(m.p.)} = 0{\cdot}07\ P^{-0{\cdot}06};$$
$$\text{and } R_{(e.e.)} = 0{\cdot}07\ P^{-0{\cdot}57}$$

where the subscripts e.p., m.p., and e.e. refer to electrolytically polished, mechanically polished, and electrolytically etched surfaces, respectively.

*Validity of Ohm's law:* It was found that this law is valid for the contact resistance, for temperatures varying from room temperature down to the boiling point of liquid nitrogen, with currents from 0·001 to 0·1 A.

*Effect of temperature:* In all cases it was found that the contact resistance increases with temperature following the linear relationship $R(t) = R_0\ (1 + \alpha\ t)$. The results are summarised in the following table.

| Specimen | Load (grams) | Temperature (°C) −175 | −120 | −60 | −20 |
|---|---|---|---|---|---|
| | | Contact resistance (ohms) | | | |
| W e.p. | 20 | — | 0·0530 | 0·0630 | 0·0730 |
| W m.p. | 20 | 0·0115 | 0·0170 | — | — |
| W e.e. | 100 | — | 0·0074 | 0·0080 | 0·0083 |
| W e.p. | 100 | — | 0·0068 | 0·0081 | 0·0089 |
| W m.p. | 100 | — | 0·0040 | 0·0061 | 0·0073 |
| Ag m.p. | 100 | — | 0·0002 | 0·0004 | — |

The mechanically polished specimen of silver was also tested, for comparison purposes.

## DISCUSSION OF RESULTS

The decrease in contact resistance with time can be explained as follows. In spite of the surface treatments, the surfaces still seem to have fine irregularities. If the contact pressure at these projecting points is greater than the yield stress of the material, plastic flow occurs. The projecting point flows into some minute indentation and the contact area becomes gradually greater, with a corresponding decrease in contact resistance.

Considering plastic flow only, and neglecting the elastic deformation which is of a smaller order, it may be assumed that a small circular area of contact is produced at each initial contact point. Its radius is given by

$$r = \sqrt{P/(\pi\ p_y)}$$

where $P$ = applied load, and $p_y$ = yield stress of the specimen. The formula for the convergence resistance $R_c$ at a surface of contact is

$$R_c = \rho/(2r)$$

where $\rho$ is the specific resistance of the material. The transition resistance $R_t$, being inversely proportional to the contact area, can be determined by the relation

$$R_t = \sigma/(\pi r^2)$$

where $\sigma$ is the specific transition resistance. Using these three equations, the total resistance can then be expressed as

$$R = \frac{\rho}{2}\ (\pi\ p_y/P)^{1/2} + \sigma\ p_y/P.$$

The resultant equation shows immediately that the contact resistance becomes smaller with increasing values of applied load. Furthermore, comparing this result with the previously given empirical formulae for the decrease in contact resistance as a function of load, it can be said that $R_c$ is the predominant factor for mechanically polished and electrolytically etched specimens, whereas $R_t$ is the major factor for electrolytically polished specimens. It is also reasonable to infer that the oxide layer formed during the electrolytic polishing process is fairly stable and not easily removed even under appreciable loads.

Whereas the mechanically polished surface is relatively rougher, the electrolytically polished surface is so smooth that at light loads it is possible that its points of contact vary in position, owing to external vibrations occurring during the tests. This would explain why the contact resistance of electrolytically polished specimens is higher at light loads, although it reaches the lowest values of all under high loads which prevent any slipping during the tests.

In regard to the effect of temperature,* reference should be made to the following equation evolved by Holm and Kirchstein on the assumption that a suitable potential barrier exists on the boundary surface :

$$1/\sigma = (8\ \pi\ m/h^3)\ [(1 + AZ)/A^2]\ \exp(-AZ)$$

where $Z = [\varphi - (e^2/d)\log_e 2]^{1/2}$

and $A = 1{\cdot}15\ (\pi^2/h)\ d\sqrt{2m}\ [1 - (e^2/2\varphi d)]$,

$e$ and $m$ being the charge and mass of an electron, $\varphi$ the work function which is hardly influenced by temperature ($\varphi \simeq 4{\cdot}54$ electron-volts), $h$ Planck's constant, and $d$ the contact distance, *i.e.*, the thickness of the intermediate layer at the contact. From these relations the value of $d$ can be computed from the specific transition resistance $\sigma$.

The contact area can be calculated not only from the plastic stress equation $\pi\ r^2 = P/p_y$ (with $p_y = 75$ kg/mm²) which has already been used in the above considerations, but also by means of Hertz's relation for elastic deformation :

$$r = 1{\cdot}1\ (RP/E)^{1/3}$$

where $R$ is the radius of the specimen (about 1 mm), and $E$ the modulus of elasticity, i.e., $3{\cdot}62 \times 10^6$ kg/cm² for tungsten. The values obtained are then as follows :—

| Load (grams) | Contact radius from yield stress eqn. | from Hertz's equation |
|---|---|---|
| 100 | 0·00206 cm | 0·00153 cm |
| 20 | 0·00092 cm | 0·000903 cm |

The real contact radii for the tungsten specimens, obtained from microscopic measurements, were smaller than the values given by either of these formulae. For silver, the reverse was found to be the case. It is conceivable that, as tungsten is a hard metal, the flow of projecting points does not easily occur, whereas the contact points of silver flow comparatively more easily.

Contact distance : As already mentioned, any surface treatment will give rise to a certain oxide layer which acts as a potential barrier. The thickness $d$ of this intermediate layer between two specimens is the " contact distance," and measured values of $d$ are included in the table given below. From these values, it may be inferred that the layer comprises two or three oxygen atoms between the two metal surfaces.

VALUES OBTAINED FROM MEASUREMENTS.

| Specimen : | Tungsten m.p. | | Tungsten e.p. | | Tungsten e.e. | Silver m.p. | Units : |
|---|---|---|---|---|---|---|---|
| Load : | 100 | 20 | 100 | 20 | 100 | 100 | grams |
| $\alpha = (R_t - R_0)/R_0\ t =$ | 4·1 | 3·5 | 2·3 | 2·1 | 1·2 | 3·8 | $\times 10^{-3}$ (°C)$^{-1}$ |
| $r =$ | 3·58 | 1·12 | 5·30 | 0·75 | 11·0 | 20·3 | $\times 10^{-4}$ cm |
| $d =$ | 3·48 | 3·41 | 4·70 | 3·88 | 5·5 | 3·50 | Angström |
| $\sigma =$ | 0·27 | 0·23 | 4·50 | 0·67 | 23·0 | 0·54 | $\times 10^{-9}$ ohm/cm² |
| $R_t =$ | 0·69 | 5·80 | 4·50 | 38·2 | 6·3 | 0·042 | $\times 10^{-3}$ ohm |
| $R_t + R_c =$ | 8·16 | 29·1 | 9·45 | 73·1 | 8·69 | 0·41 | $\times 10^{-3}$ ohm per °C |

*It has been assumed that the contact radius remains constant with the temperature although strictly speaking it varies since the yield point, and hence the hardness of the metal, is a function of temperature.

# Welded Machine Tools

By O. Bondy, A.M.Inst.C.E., M.I.Struct.E., M.Inst.W.

*In recent years, the change-over from cast iron to fabricated steel produced remarkable novel types of machine tools. Some reasons are given for these developments. The designer has to play the leading rôle. Comparisons between alternative types of construction often prove that the fabricated machine tool is superior both in economy and performance.*

It is not surprising that the heavy types of machine tools with solid cast iron stands and bed plates were among the first for which alternative designs for welded fabrication were prepared. While, in some cases at least, the weight of the heavy cast iron parts may add to stability and performance, it was soon discovered that a considerable proportion of dead weight could be saved without losing the advantages in service. Very often, the reduced weight of welded fabrications leads to direct savings in cost, but apart from this consideration, there are indirect savings, e.g., because of easier handling in the workshops, reduced freight and shorter delivery times. The better appearance of a well-designed welded machine tool is an advantage that is not always easy to evaluate, but it often leads to improved sales, especially in markets abroad.

Although most of the illustrations refer to the heavier types of machine tools produced by welded fabrication, the designer's skill actually shows at its best when replacing cast details of older types by fabrication. Here, the immediate advantages lie not so much in the saving of weight, which may not be decisive, but rather in improved performance. The designer will soon learn by experience ; he will make full use of the larger degree of freedom afforded him in shaping the individual parts as he likes and in placing the material just where it is wanted. Repairs to machines in service can be carried out by welding ; there need be no waiting for spare parts, and very little, if any, interference with workshop routine.

However, with the shortage of iron and steel, which has to be taken into account not only for the present but probably for some time to come, a reduction in the amount of material is of paramount importance. For 1952, the production of steel in Great Britain is expected to fall short of requirements by approximately 1½ million tons. Any small proportion saved in any field of engineering will allow us to produce more from available supplies. Replacing heavy castings by fabricated steel of appropriate design should save a considerable proportion of weight which can be put to better use in producing more machines, of which we are so badly in need.

It is an interesting fact shown by statistics that relatively more cast iron is being used in Great Britain than in other European countries, in proportion to the total consumption of steel.

" . . . Throughout the world, the production of iron castings is falling relative to the use of steel; in 1950, iron casting production in Great Britain was 21 per cent compared with an average of 16 per cent for Europe and the United States of America . . . The supply of cast iron should be curtailed in favour of steel . . . why is it that this country absorbs so much larger a proportion of cast iron than other countries' ? . . . . "

Only a part of this question may be answered by the fact that the change-over from cast iron to welded steel in various fields of engineering has started a good deal earlier in Continental countries than in Great Britain. It may well be that in a few years' time these percentage figures will be rather different because of the tremendous developments in welded fabrication which received their strongest stimulus from the necessity to save iron and steel.

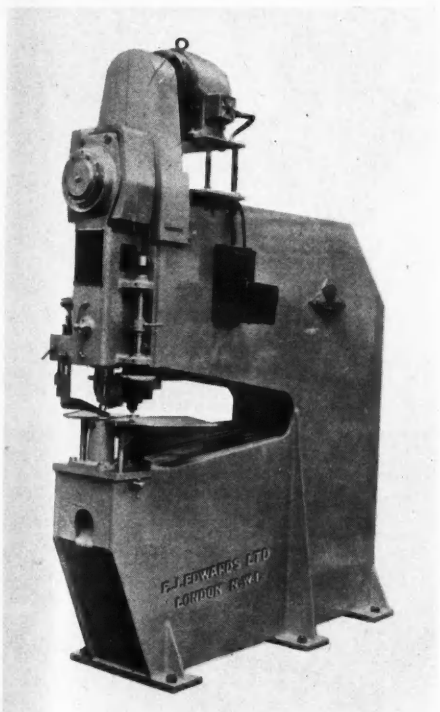



Fig. 1. **Universal Nibbler-Shearing Machine for cutting ¼ in. mild steel plate.**

Main frame of welded steel plate, heavily braced. 8 hp motor drive, 42 in. throat depth, 35 cwts. net weight. (F. J. Edwards Ltd., London, N.W.1.)

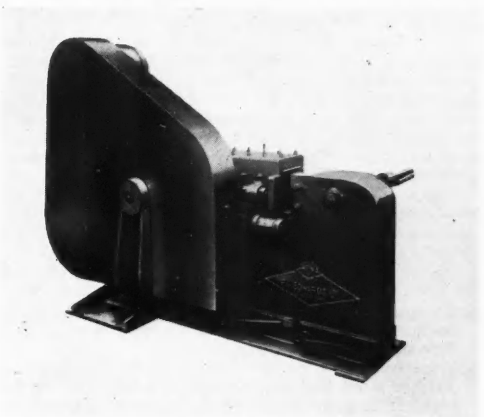


Fig. 2. **Bar Cropping Machine for floor mounting.**

Welded steel plate frame and welded brackets, levers and toothed gears. Capacity 2 in. diameter mild steel rod, or bundles of 64-¼ in. dia. rods. (F. J. Edwards Ltd., London, N.W.1.)

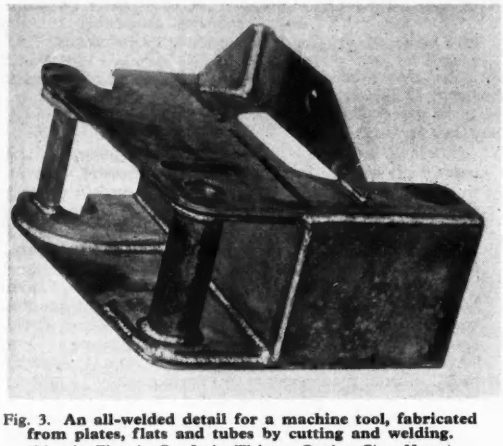


Fig. 3. **An all-welded detail for a machine tool, fabricated from plates, flats and tubes by cutting and welding.** (Lincoln Electric Co. Ltd., Welwyn Garden City, Herts.)

It would be a mistake to overlook the considerable advantages which cast iron, as a raw material, possesses as against other materials. Mass production by casting is definitely more economical than other methods of fabrication, and this is likely to remain so. There are, of course, cases for which alternative types of design have to be compared. Where corrosion matters, cast iron parts may be preferable to steel, the latter requiring protection and maintenance. The importance of dead weight in cast iron bases and stands is sometimes being exaggerated. In any case, addition of cast iron is a rather expensive way of providing the required stability. It may be just as effective and probably very much cheaper to fill the hollow stand or base with concrete. Cast iron machines may show better performance than steel when affected by oscillating or vibrating loads. The damping capacity of cast iron is certainly a valuable quality.

On balance, however, the advantages of fabricated steel are in most cases decisive, always assuming that the machines are properly designed and fabricated by modern means.

What are these *advantages of fabricated steel* in machine tool construction? To enumerate just a few:

Individual parts of the machine can more easily be designed according to the type and amount of loading they are expected to carry.

The designer has complete freedom in shaping individual parts and complete assemblies as he thinks best. There are very few restrictions imposed in fabrication by welding, certainly fewer than in production by casting.

The variety of rolled and cold-drawn shapes welded into sub-assemblies permits saving in weight. Rolled steel sections, circular and rectangular tubes and folded plates can be combined in infinite variations.

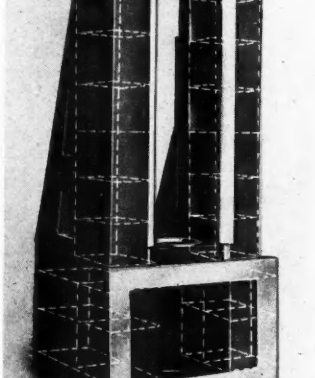
Young's modulus for mild steel is about one-and-a-half times that of cast iron. The deformation of steel members is therefore only about two-thirds of cast iron members of similar dimensions and loading.

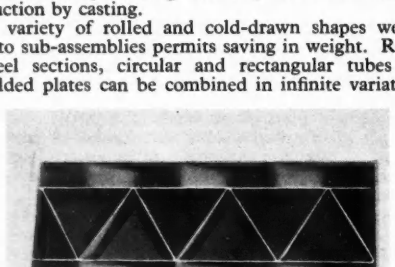
Repairs and maintenance work are easily carried out by welding. Worn parts can be reinforced by weld metal of increased hardness, thus prolonging the life of vital components.

This list could be extended and it is by no means exhaustive. Those works which have made a start with the re-design of machine tools for welded fabrication will find that the scope for welding is widening as their experience grows. In this field, as in others, experience is the essential thing, because the performance of a machine tool cannot always be predicted in mathematical terms. Series of experiments may be required, especially where dynamic loads are the decisive factor.

In this connection it may be mentioned that *paper models* were found to give valuable indications regarding the stability of fabricated bodies. Problems of stiffness are usually complex in their mathematical aspects, especially where the buckling of thin sheets and walls is concerned, and the behaviour of such paper models has provided valuable guidance[2].

The *welding processes* used in the field of machine tool fabrication are: gas welding, mostly by the oxy-acetylene process, for thin sheets and tubular work; electric arc welding, for material from about $\frac{1}{8}$ in.





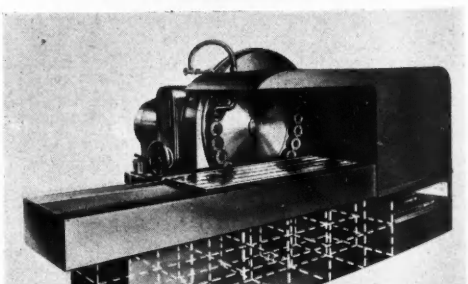


Fig. 4. **Three examples of cellular welded fabrication for machine frames.** (Diskus Werke A.G., Frankfurt, and Rockwell Machine Tool Co. Ltd., London, N.W.2.)

thickness upwards (flanges up to 4 in. and even more have been welded[3]); electric resistance welding, for thin sheets, also for the cellular types and castellated construction.

The fields of application for these three main welding processes can only be indicated in an approximate manner. There is considerable overlapping between individual processes and there are expert electric welders capable of producing sound arc welds in 16-gauge and even 20-gauge steel sheets, but, as a rule, the thin sheets will be much easier to join by resistance welding or by oxy-acetylene torch.

The *drawing office procedure* may be indicated as follows, assuming that a cast iron design is to be re-designed for welded fabrication:

(1) As an initial procedure, the whole body should be split up into simple components.
(2) For each of these components, the structural function must be clarified, as also the boundary conditions, i.e., the conditions of support and restraint.
(3) The shape of the individual components has to be worked out on rational principles, from the above assumptions. The special requirements of welding fabrication have to be taken into account.[4]

Detailed recommendations of this kind were drafted in wartime, when the saving of material was of particular importance. An Advisory Service on Welding at the

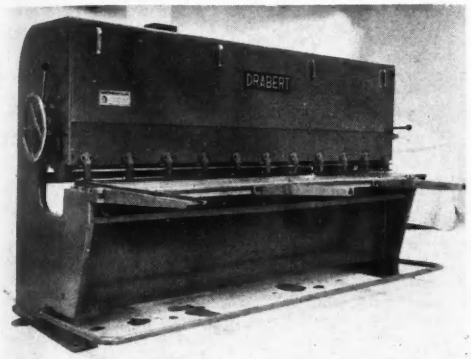



Fig. 5. **98 in. sheet metal " Drabert " guillotine, all-welded steel frame of fabricated units.**
The drive is built into the hollow crown of the machine so as to give unrestricted clearance between the columns, which have deep throats to permit the handling of sheets of considerable width. Clamping by hydraulically actuated pads. (Rockwell Machine Tool Co. Ltd., London, N.W.2.)

Ministry of Supply issued a memorandum which is as important to-day as it was then.[5] Its recommendations, illustrated by simple sketches and short explanations, can well form an elementary introduction to re-designing operations in any drawing office concerned with machine tools.

Recommendations in a much more elaborate form were prepared by the Committee of the British Welding Research Association, and published in 1948. They give due space to considerations of *fatigue loading* which figure prominently in modern machine design. The types of dynamic loading, apart from shock and impact, as are met with in practice vary considerably, and it is often necessary to work to certain limits based on the endurance strength of a praticular type of welded joint under pulsating, repeating, reversing or alternating loads. With certain types of loading, the stress range begins at zero, developing tension or compression or both, while with other types of dynamic loading the oscillations return to a base line representing a static tension or static compression. Maximum stress ranges for many types of welded joints and different types of loading are given in tables and the figures are based on 2 million stress cycles. This figure is usually accepted as a basis in structural engineering, but in mechanical engineering 10 million might form a more suitable basis, or even 100 million stress cycles, as is sometimes assumed in aircraft engineering.

The subject of fatigue has been very much in the foreground during the last few years. Large-scale research programmes have been carried out and are proceeding at the laboratories of the British Welding Research Association at Abingdon and at Cambridge University.[6] Reports published from time to time deserve the attention of the designer of modern types of machine tools. Earlier research work in this country was discussed before the War and valuable observations were collated in a book published in 1935.[7] At that time, Professor F. Bacon drew attention to the importance of relieving stress concentrations which may lead to micro-cracks and develop into complete failure. One of the means to prevent such effects is the provision of stress relieving grooves, which are fairly well known, not only in machine design, but in other fields as well.

The fabrication of *details* by welding has been mentioned above, indicating some of the advantages obtained as compared with castings. There is an infinite variety of types of levers and they can usually be

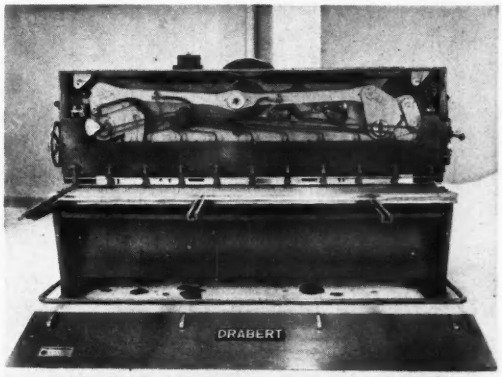



Fig. 6. **98 in. " Drabert " guillotine, cover removed to show ram mechanism.**

made at very low cost. These levers, consisting of the hub, the strut and the connector, can be fabricated at small cost from standard material, sometimes even scrap material. The hub can be cut from a piece of tubing and, in general, tubes or box sections are easily fabricated by welding. Bosses can be welded to the ends of the individual parts, and if it is a question of foot levers, a small floor plate, perhaps cut from a piece of chequered plate, will serve for the purpose.[8] Other details which will at once attract the designer's attention, because they offer no problem whatsoever in welded construction, are machine parts such as bosses, bearings, pedals, pins and crankshafts, cams and eccentrics. They are fabricated singly, then connected to form sub-assemblies and assemblies, the guiding principle being " one part at a time." The raw material used is usually mild steel in the shape of rolled steel sections, joists, channels, tees, tubular steel and hollow box shapes. Gear wheels are often fabricated from different qualities of steel, thus effecting an appreciable saving in cost. Individual teeth which should wear out can be rebuilt by welding, and this, of course, is another important advantage of fabricated steel design as against castings.

*Composite construction* in combinations of casting and welding proved to be an ideal solution in many cases.[9] The hubs of wheels from the smallest to the largest diameters may be preferable as steel castings, and so may be, for instance, the outer rims of toothed wheels. Web members and spokes, however, are not exposed to wear and will be just as efficient and cheaper in mild steel. It is possible to weld a casting to another casting, or a steel casting to wrought steel products. Some steels are not as readily weldable as others, but special operational techniques have been worked out and difficulties overcome.[10] Steel castings, grey cast iron, mild steel and forgings can be joined by welding and complicated castings may be split into their simpler components.

An interesting comparison refers to three alternative designs for one and the same lathe.[11] The leading dimensions were exactly the same, including the distance between centres and the height of centres. Built with a cast iron stand, the total weight was 18,000 lb. The stand replaced by a horizontal tube worked out at

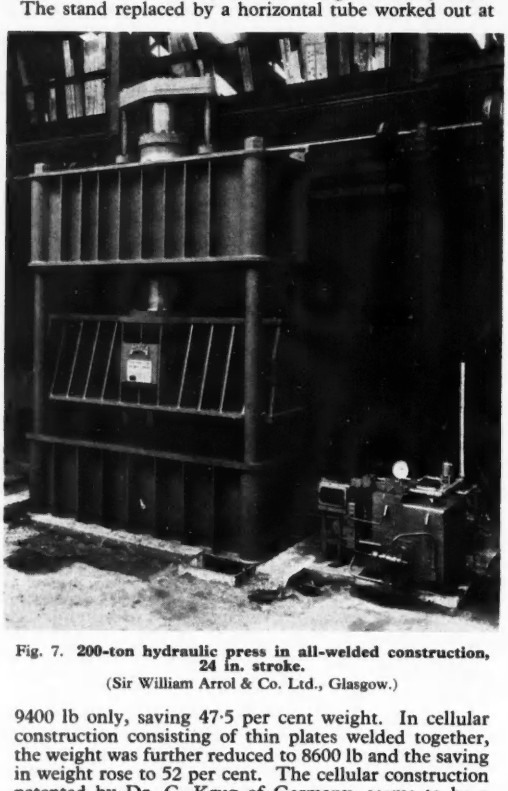


**Fig. 7. 200-ton hydraulic press in all-welded construction, 24 in. stroke.**
(Sir William Arrol & Co. Ltd., Glasgow.)

9400 lb only, saving 47·5 per cent weight. In cellular construction consisting of thin plates welded together, the weight was further reduced to 8600 lb and the saving in weight rose to 52 per cent. The cellular construction patented by Dr. C. Krug of Germany, seems to be a promising development which was only made possible by welding. Resistance welding is the ideal method for connecting these plates folded along the edges, and extraordinary stiffness is obtained with a minimum of material. Some illustrations show this type of design, which may be expected to widen its fields of application.

Special applications of welding can only be quite briefly mentioned, e.g., the *hard surfacing* of worn parts, which thus are made tougher than new ones. An oxy-acetylene flame would deposit metal on the worn part, which is then re-machined to its original dimension. At negligible cost, wearing surfaces and teeth can thus be restored to their full size and effectiveness.

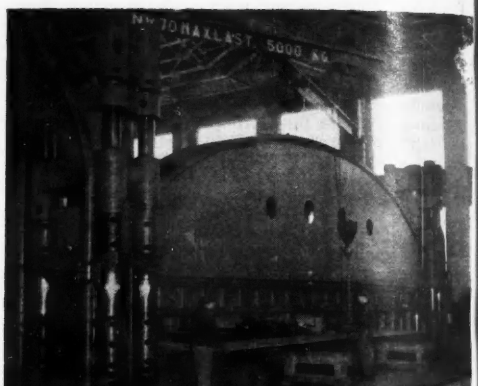


**Fig. 8. 1200-ton hydraulic press, built entirely of rolled steel by welding, for shipyards at Göteborg, Sweden.**
Max. thickness of flange plates for upper and lower table is 4¼ in., max. thickness of web plates 2 7/8 in. Total length of the press tables is about 46 ft, their maximum depth at midspan 10 ft and their width 3 ft. The upper table weighs 47 tons, the lower table, of similar shape but reversed and below ground, weighs 56 tons. The total weight of the press, including accessories, is about 250 tons. ("Svetsaren," No. 4, 1951, ESAB, Göteborg, Sweden).

*Atomic hydrogen welding* is one of those modern welding methods which proved extremely helpful in certain fields, e.g., for the manufacture of press tools by depositing tool steels on mild steel blanks. Welding sets of 50 A are being used also for repairing broken shanks of drills and reamers, fractured collets and many other workshop production tools.

These few examples may have shown the practically unlimited scope for using modern welding techniques. It all depends on the designer. If he shows skill and imagination, he will soon make a complete success of it. If the designer has produced a really efficient design, he will be able to rely on the workshop to make a good job of it. Nowadays, the welding operations themselves will hardly offer any particular difficulties. It is true that many questions still require research on a large scale. The fact that such research is well in hand may be reassuring to many manufacturers, who will be able to fall back on an ever-growing amount of practical experience.

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# The "2000-OHM Milliammeter" Method for Daily Checking of L.T. Three-Phase Networks

By M. VILLAIN. (From *Electricité*, Vol. 36, No. 181, March, 1952, pp. 59-63, 4 illustrations.)

CONTACT with a phase conductor of a L.T. three-phase distribution network of 127/220 volts with an earthed neutral may be extremely dangerous. The resistance of the human body depends on the applied voltage and is between 1700 and 3700 ohms with a voltage of 127 volts. Taking a mean value of 2000 ohms for the body resistance $R_c$, the intensity of the current passing through the body under the above conditions will be : $i = U/R_c = 127/2000 = 0{\cdot}063$ ampere ; this is considerably higher than the limit intensity of 25 milliamperes, which is regarded as dangerous.

Contact with a phase conductor or neutral of networks of the above voltage is harmless (a) when the neutral is insulated, (b) when the entire network is insulated from the earth (with completely insulated generating plant and receiving equipment), and (c) when the capacitance of the entire system relative to earth is negligible. These conditions are found only in very small networks. Although the circuit is earthed through the human body, there is no current flow, since a return path to another phase of the transformer is lacking. However, the risk is just as great as with the networks previously referred to, since an earth fault may occur at any instant on the neutral or one of the phases. In such cases, only the earthed conductor can be touched without risk, since the voltage relative to earth of the two phases in good condition is the combined voltage $U = 127 \times 1{\cdot}73 = 220$ volts.

Between these extreme cases, there is an intermediate range of conditions when the network has more or less marked defects in its insulation. The leakage current is then capable of causing a shock which may even be fatal if the 25-milliampere limit is exceeded. Thus, a phase with a generally defective insulation can cause fatal injuries as soon as its resistance drops to a value below $R_d = (U/i) - 2000 = (220/0{\cdot}025) - 2000 = 6800$ ohms. It is, therefore, necessary for industrial electricity producers to ensure that their networks with an insulated neutral are free from faults of this nature. A daily check by the 2000-ohm milliampere method will then be useful.

In various countries, such checks have been made compulsory by official regulations. In Great Britain, where the method was first applied, the Board of Trade rules state that " The insulation resistance of a complete circuit, including its associated equipment, must be such that if any part of this circuit is earthed through a resistance of 2000 ohms, the current losses should not exceed 0·040 ampere for continuous current, or 0·020 ampere for alternating current." Similarly worded by-laws have been recommended by the French electricity producers' associations for use by their members, the limits, however, being raised to slightly higher values (0·050 ampere for d.c. and 0·025 ampere for a.c.).

The choice of 2000 ohms as a representative value for such tests was based on the following considerations : (a) This figure can be assumed to apply to the resistance of a " standard " human body in the most adverse case, where the tissue resistance is 500-1000 ohms, the skin impedance is broken down, and a further 1000 ohms is added for the resistance of the boots. (b) 2000 ohms is a suitable value for measurements, and (c) it is also suitable for ensuring the safe operation of electrical equipment. As this is a compromise value, the instrument indication is likely to be higher than the actual current passing through a human body when the applied voltage is less than 50 volts, since in this case the skin impedance may have remained at a high value if the body is in a dry condition.

The French regulations referring to the method of checking low-tension three-phase networks are not clearly expressed. They state that " In installations of Class I where the neutral is not earthed and which comprise motors with a total power of at least 5 kilowatts, an attendant should verify daily at the distribution panels that there is no abnormal variation of voltage between each pole or phase and earth. This is a necessary check of the insulation of the neutral."

Although it is true that the risks increase with discrepancies between the voltages, cases frequently occur in which the insulation faults are equally distributed among the three phases, or where the fault is on the neutral. The voltages can then still be $3 \times 127$ volts for the above network. Thus, voltage variation alone is not a sufficient indication. Voltage measurements between the neutral and earth are not mentioned. Furthermore, the " voltage to earth " is not defined in a way that can be clearly appreciated by the average operator. An idea of the difficulty is obtained by considering the graph of Fig. 1.

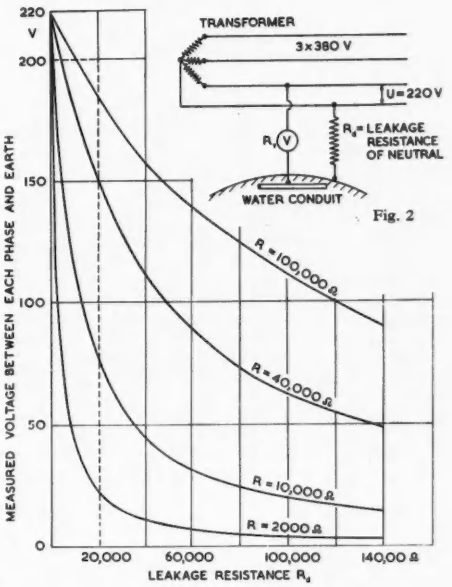


Fig. 2

Fig. 1. **Resistance $R_d$ of the insulation defect of the neutral, in series with the four voltmeters (with an internal resistance $R_v$) used for successive measurements between earth and each of the three phases of the network.**

This represents the conditions for a star-connected source of $3 \times 380$ volts when the neutral has an insulation fault $R_d$ which may vary from zero to 160,000 ohms. The four curves are the " voltages to earth " as defined by the above mentioned regulations, for the phases *A*, *B* and *C*, successively connected to earth by means of voltmeters with internal resistances $R_v$ of 2000, 10,000, 40,000 and 100,000 ohms, respectively.

When the neutral is earthed so that its resistance is $R_d = 0$, the voltmeters give correct indications of the voltages to earth, e.g., $iR_v = U = 0{\cdot}11 \times 2000 = 0{\cdot}022 \times 10{,}000 = 220$ volts. But if the leakage resistance of the neutral is, say, $R_d = 20{,}000$ ohms, the four voltmeters will show voltages of 20, 73, 146, and 183 volts, respectively, since the current is determined by

$= U/(R_c \times R_d)$ and the indicated voltage is $iR_v = U - iR_d$ in each case. It is therefore advisable to fix the value of the resistance of the instrument to be used.

Industrial firms may find it convenient to use a 2000-ohm voltmeter mounted on the main distribution panel for the measurement of voltages between phases, but in such cases the dial should be provided with an additional scale, in a different colour, graduated in miliamperes, to eliminate any uncertainty.

The method is an extremely effective means of indicating a serious fault without stopping the entire generating plant. Milliammeter readings can be taken during the off periods, before restarting the motors which operate intermittently, or after cutting out the various conductors one after the other for a brief period.

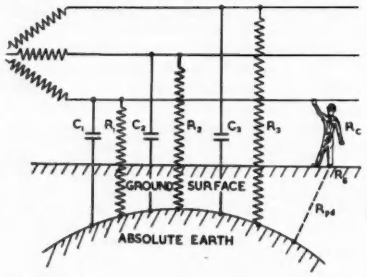


Fig. 3.

Networks frequently present much more complicated conditions than those illustrated in the simple case of Fig. 1. As shown in Fig. 3, the body resistance $R_c$ of a person may be in series with the ohmic resistance $R_d$ of a fault on a conductor. It is also in series with the resistance of the shoes $R_s$, and the resistance $R_{pd}$ between the ground and the absolute earth. It may also be in parallel with another insulation fault $R_{d3}$ and a capacitance $C_3$ and further series-connected with the network voltages through complex impedances $R_1$, $C_1$ and $R_2$, $C_2$. The 2000-ohm milliammeter method gives reliable indications even in this complex case, although its readings may tend to be on the high side.

The French electricity producers' associations therefore recommend the use of this method in the following cases :—(1) on all L.T. networks with an insulated neutral which are supplied by a star-connected source, even for $3 \times 500$ volt networks which do not include motors ; (2) on networks of similar voltage having a delta-connected source and no phase conductors intentionally earthed ; (3) on networks with a star-connected source having an earthed neutral, or very extensive networks with a high capacitance relative to earth.

The possible dangers due to earth faults will now be considered more closely. First of all, single-pole contacts with either of the two undamaged phase conductors will be more dangerous, because the operator is exposed to the combined voltage instead of the star voltage.

Furthermore, when the neutral is intentionally earthed by means of a plate of resistance $R_n$ and a low-resistance earth fault occurs on one of the phases, it is known that the section of the network in which the fault is situated is not necessarily separated from the rest of the network by the operation of a fuse or a circuit-breaker. The earthing frequently results in a permanent leakage current $I$ passing through the earth surface to the absolute earth. This would be indicated by an ammeter inserted on the neutral ahead of the $R_n$ plate.

This earth current is particularly dangerous because it creates a voltage drop $IR_m$ on the earth plate $R_m$ and the metalwork of the equipment in contact with a phase conductor, and the personnel may not be aware of its existence. In the case of Fig. 4, the leakage current is $I = U/(R_d + R_m + R_n) = 220/(0 + 15 + 5) = 11$ amperes. The mass of the motor casing and any parts of machines connected to the same earth point will then have a potential $IR_m = 11 \times 15 = 165$ volts relative to the absolute earth. This "mass voltage" would be very dangerous for an operator touching, for instance, a metal lever of a circuit-breaker, the casing of which is connected to the earth wire. Another effect of the earthing is to raise the neutral to a voltage $IR_m = 11 \times 5 = 55$ volts, whereas the neutral is usually harmless when no current passes through the plate $R_n$.

A third, even more insidious, effect may occur when the earth plate of the neutral is not deeply buried and therefore has an abnormally high resistance $R_n$. A fraction $i$ of the total current $I$ diffusing through this plate may then be flowing through two points $D$ and $E$ which are about one step apart on the surface of the ground, thus creating a voltage drop which may be high enough to be fatal to a person or animal passing in the vicinity of the earth plate. This "step voltage," which causes a foot-to-foot shock, cannot be calculated.

For networks with an earthed neutral, it is not essential to use a 2000-ohm milliammeter as an indicating instrument. A voltmeter with an internal resistance of any magnitude may be used, since it is in series with the low resistance of the earth plate of the neutral. An even simpler method of indication is to use a set of three light bulbs permanently connected between earth and each of the three phases. The bulbs will glow with the same intensity if there is no insulation fault on the phase conductors. As soon as a low-resistance fault occurs on one of the phases, the corresponding light will fade out while the other two will shine more brilliantly, being supplied with the combined voltage.

It should also be noted that the milliammeter method is not applicable to networks with a delta-connected source, one phase of which is intentionally earthed, since the voltage to earth is then always the maximum value between the phases.

It would, therefore, seem desirable to provide for an automatic checking of networks with an insulated neutral instead of leaving this to the individual operators. It would be an advantage to have for this purpose an electric clock mechanism which would control the necessary contacts and periodically check the various circuits, the measurements being made automatically in periods of a few seconds' duration.

## THE PRESENT AND FUTURE OF THE BRITISH MACHINE TOOL INDUSTRY

(*Concluded from page 237*)

entered the machine tool field and, with customary markets near at hand closed to her, is likely to become a competitor to be reckoned with in a wider sphere, particularly in the Indian market.

Counteraction to this loss of markets lies in the development of business possibilities in other territories and efforts to break into markets from which British machines have been virtually excluded, e.g., the U.S.A., and those where there is a potential field for supply but where hitherto the proportion of business secured by British manufactures has been infinitesimal, notably South America and the Canadian market already referred to.

The solution of the economic situation, both present and future, within the British machine tool industry and the ensurance of its fullest contribution to the economic recovery of the nation will involve the high production of first-class machines at minimum cost and the adoption of bold and enterprising sales efforts abroad. This pre-supposes recognition of the economic importance of the trade by the government of the day who, in the interests of the national well-being, should assist and encourage its progress by freeing it from frustrating and irritating regulations and by reducing the crippling effect of taxation.

# International Machine Tool Exhibition—London, 1952

*The second post-war machine tool exhibition organised by the Machine Tool Trades Association opens at Olympia, London, on the 17th September. It is expected that some 2000 machines produced in this country, on the Continent and in the United States will be shown, together with a large amount of small production and auxiliary equipment, as well as measuring and testing apparatus. The exhibits shown on individual firms' stands will be accommodated in all the halls at Olympia, including the first and second floors of the Empire Hall and all the galleries. It is expected that the Exhibition will be visited by a very large number of foreign engineers and buyers, and official representatives of some twenty National Machine Tool Associations from overseas will also attend. It promises, therefore, to be an event of major importance in its own sphere and the keen interest shown by potential visitors from all parts of the world stresses its international character. H.M. Minister of Supply, the Rt. Hon. Duncan Sandys, M.P., has accepted an invitation to visit the Exhibition on the 18th September, when he will be received by the President and Officers of the Machine Tool Trades Association prior to a tour of the Exhibition and a reception. On the 25th September, a reception and luncheon will be given by the President and Officers in honour of distinguished visitors from abroad.*

*Due to the vast number of exhibits and their varied nature, it is virtually impossible to provide a comprehensive survey. Further, as the exhibits are not grouped functionally but are shown in mixed groups on individual exhibitors' stands, any common trends in machine tool development since the previous exhibition of 1948 will become apparent only after thorough study and consideration. For the following preview of the Exhibition, therefore, a number of exhibits have been selected from the various sections, the main criteria being newly developed designs and new or interesting applications of established designs. The descriptions of a further number of interesting exhibits will be published in the next issue.*

An interesting new machine, the Lodge and Shipley 60 in. Chucking Lathe, Fig. 1, will be shown on the stand of **E. H. Jones (Machine Tools) Ltd.,** who market the machine in this country. It is of a rather unconventional design in that the bed is in the shape of a T, with the carriage carrying ways at right angles to the axis of the headstock. Facing can therefore be accomplished by a movement of the carriage. The machine is intended particularly for facing, turning and boring large-diameter, thin-walled and short work. A tracer control can be incorporated and a steplessly variable speed control, to give constant cutting speed for facing, can also be built in. The latter feature should be most useful in enabling a consistently good finish to be obtained over a large face. The machine is normally used with a chuck or face plate, but components with unmachined extensions can be accommodated as the headstock bore is 11½ in. Loading and unloading are from the front, and the carriage can be traversed right to the end of the bed. The maximum swing of the machine is 60 in. and the maximum turning length depends on the method of holding the component. The absolute maximum is about 15 in. The machine is compact and occupies very little space in relation to its work capacity.

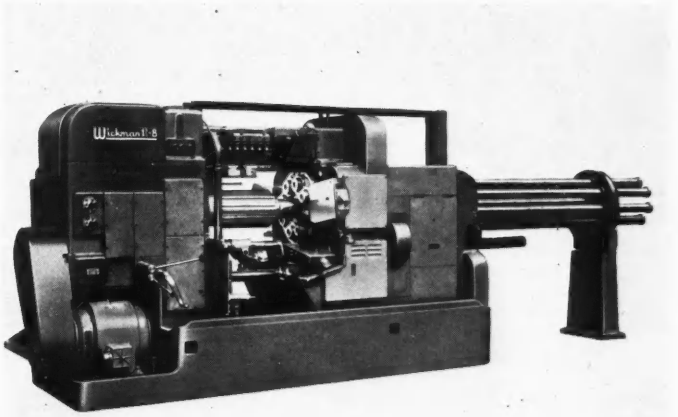


Fig. 2.

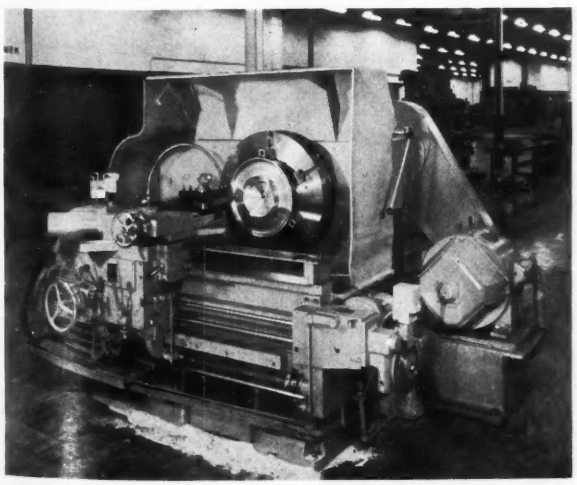

Fig. 1

A new machine, shown in Figs. 2 and 3, which extends the range of their bar automatics will be shown by **Wickman Ltd.** It is an eight-spindle machine with 1¾ in. bar capacity. The machine is very rigid as the frame is of the same size as is used in the larger machines.

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# Churchill

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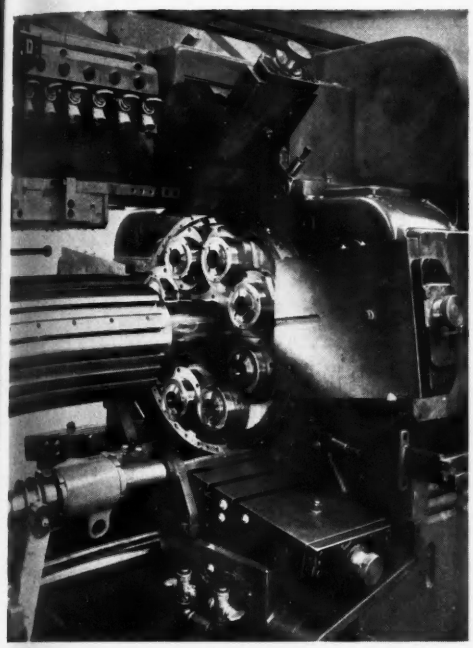


Fig. 3.

The usual Wickman auto-setting mechanisms, enabling changes of tool feed strokes and bar feed without cam changing, as well as other features used in the larger Wickman machines, are incorporated in the new machine. Eighteen tooling faces are available, eight of which are on the main tool block, two on independent tool slides, four on cross-slides and four on two double-station auxiliary cross-slides. Two different components can be produced at each indexing as the bar can be fed in two stations and the spindle drum can be arranged for double indexing. The bar feed can be extended to 10 in. from the normal 5 in. by using a special bar feed cam. The maximum turning length is 9 in. and a very wide range of cycle times from 8 seconds to 16 minutes can be obtained by fifty feed gear combinations. The 40-hp motor provides 24 spindle speeds ranging from 96 to 1243 rpm.

A new 5¼ in. six-spindle automatic chucking machine will be exhibited for the first time by **B.S.A. Tools Ltd.,** Birmingham, by whom it is manufactured under licence. As shown in Fig. 4 it is strongly constructed to permit fast machining, all mechanisms are fully enclosed, it has rapid indexing to reduce idle time to a minimum and each slide has independent cam control. The machine has hydraulic control, the unit operating the spindle clutch and brake being fully automatic, whereas the hand-operated unit for chucking is semi-automatic. Chucking pressure is adjustable to suit the nature of the component. Sight gauges are provided for checking the pump pressure for the chucks, clutch and brake. Loading and unloading on one spindle is carried out while all the other positions are operating, so that the only non-productive time is that needed for indexing the spindle carrier and moving the tools to and from the work. The design of the machine is such that these times are reduced to a minimum. The machine has four massive cross-slides and their movement is limited by positive adjustable stops. Fine adjustment is provided so that the tools need not be moved for small changes in depth of cut. The cams are easily accessible and can be changed without disturbing the drum. Threading and high-speed drilling attachments, independent turret slides fitted to the top rail and a wide range of other auxiliary equipment are available. The maximum swing is 5¼ in. and the maximum turning length is 4 in. The 15-hp motor gives spindle speeds ranging from 172 rpm to 1492 rpm.

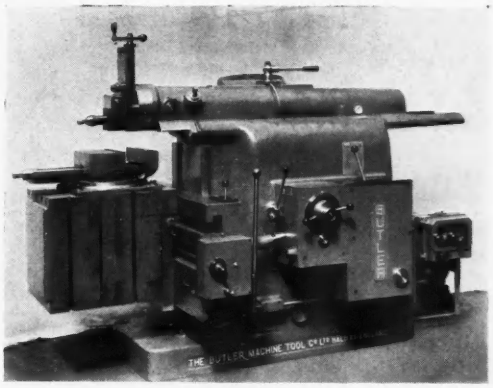


Fig. 5.

Another new machine, which is being shown for the first time, is the 26 in. Super Shaper manufactured by **The Butler Machine Tool Co. Ltd.,** of Halifax. The machine, shown in Fig. 5, is similar in design to the 18-in. model, and the drive is through a friction clutch to an eight-speed gear box. The stroke wheel,

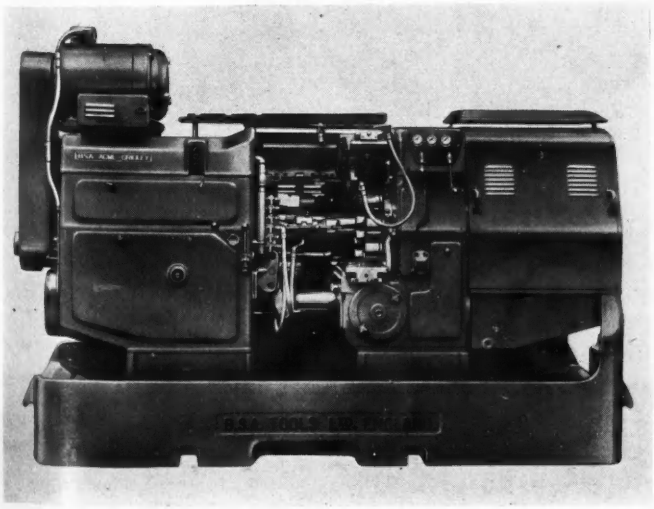
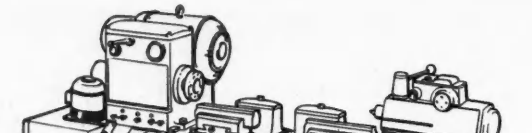


Fig. 4.



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which revolves round a large fixed bearing in the body, is of single helical construction. The feed is operated by a cam and this can be changed while the ram is in motion. Horizontal power traverse to the table and automatic down-feed of the tool box are available. All the lubrication on the machine, which includes that of the gearing and gear box bearings, link motion, ram slides and feed motion, is supplied by a gear pump, and an oil pressure gauge is provided for checking the operation of the whole system. The machine, of very sturdy construction, can be equipped with all the normal shaping machine accessories. The maximum stroke of the ram is 26 in. and the table surface is 25 in. by 18 in. The horizontal and vertical movements of the table are 30 in. and 14 in. respectively. The 12-hp motor runs at 900 rpm and provides 9 to 100 cycles per minute.

A new Universal hobbing machine, Model HV24, is being exhibited by **W. E. Sykes Ltd.,** of Staines. The machine produces spur and helical gears, splines, sprockets, worms and wormwheels and has a capacity of 24 in. diameter × 15 in. face, with a maximum of 3·5 D.P. As shown in Fig. 6, the hob head is mounted on a moving column, while the work-table is fixed. Accuracy in setting is ensured by Vernier scales for the angular setting of the hob head, a micrometer device for centering the hob itself and a large micrometer thimble for regulating the depth of cut. All the controls are grouped for convenience of operation, and a single lever with interlocking controls operates rapid traverse movements. These include movements of the column in both directions and of the hob slide. The machine has an adjustable frame construction and, if required, can be supplied with differential feed gear and an interchangeable axial-feed hob head.

A special hydraulically controlled deep hole drilling machine, Fig. 7, operated on a controlled cycle is being shown by **Adcock and Shipley Ltd.,** Leicester. The rotor-stator unit driven drilling heads are fed hydraulically step-by-step, the number and depth of steps being variable to suit the drilled material. Rapid approach and rapid return are used to shorten cycle times. Mechanically, air or hydraulically operated fixtures can be used for clamping the components, and coolant under high pressure is supplied for cleaning the swarf out of holes as the drills are withdrawn. The machine is suitable for drilling deep holes in components such as connecting rods, crankshafts and swivel pins. The particular machine on show has an indexing turret type

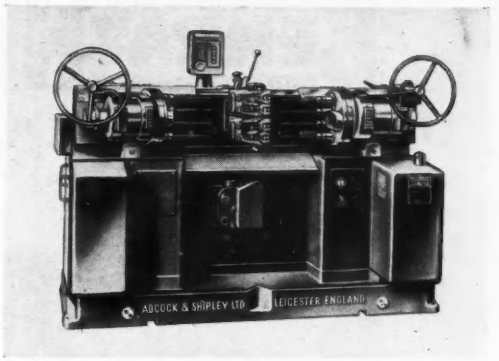


Fig. 7.

fixture which enables loading and unloading to be carried out at one station whilst drilling is proceeding at the other station.

A new trend in machine tool construction is typified by the machine units manufactured by **Oerlikon Italiana** of Milan, Italy, and exhibited by the U.K. distributors, the **Elgar Machine Tool Company Ltd.** These units, which are produced in various sizes and various types suitable for drilling, reaming, tapping and milling, incorporate individual spindle drive and feed mechanisms and can be used singly or built into special machines. The smaller drilling units have cam feed, are provided with rapid approach and can be fitted with multi-spindle heads for the simultaneous drilling of a number of holes. Simultaneous multiple tapping is also possible, with each tap being fed independently. The two smaller units have a capacity in steel of ½ in. and 1 in. and are provided with driving motors of 1 hp and 3 hp respectively. The larger unit, UFM-2, has its feed and rapid traverse motions imparted by a screw, which traverses the headstock on the bed guideways. It has two motors, one of which incorporates a brake and actuates the approach and rapid traverse motions, whilst the other motor provides the power feed and spindle rotation. Pick-off gears are used for speed and feed selection, and adjustable trip stops are used for determining the length of rapid approach, power feed and rapid return. The unit can be provided with an attachment giving adjustable stroke for operations requiring reciprocating feed and withdrawal. The unit can be fitted with a main motor of up to 6 hp capacity; the maximum headstock traverse is 18 in. and the maximum drilling capacity in steel is about 1½ in. The milling units, also designed to operate on an automatic cycle, can be used either with face cutters or multiple cutters mounted on an arbor. In the latter case the arbor is supported by an overarm. As with the large drilling unit, the unit has two motors and both the power feed and rapid traverse motions are provided by a screw mechanism. The spindle drive is by belts and pulleys or by gears, depending on the machined material and machining speed. The main motor can be up to 8 hp capacity, the total weight of the unit being 1650 lb. The unit can again be used on its own, or can be com-

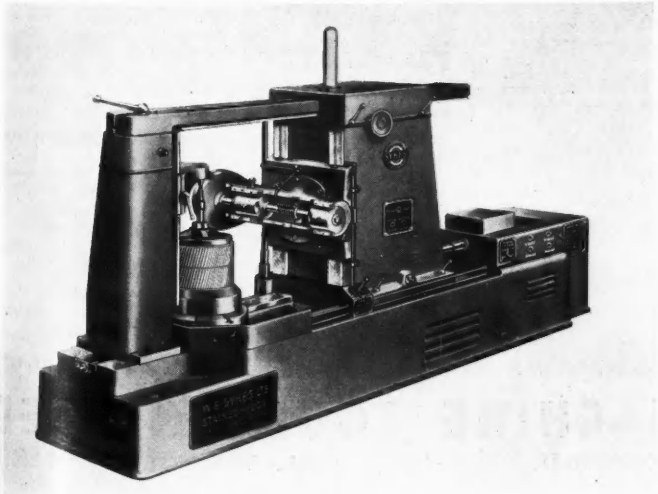

Fig. 6.

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**JUNG, KARL G.m.b.H., GOEPPINGEN-WUERTT.**

Surface grinding machines. Rotary table surface grinding machines.

**ZIMMERMANN MASCHINENBAU G.m.b.H., MULHEIM.**

"Reinhold" pedestal type drilling machines.

## BENRATH MACHINE TOOLS LIMITED

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bined with other similar or different units to form a special machine for quantity production.

Among the heavy machines exhibited, there will be a large vertical milling machine, Model C.V.M. 60, which is the latest addition to the range manufactured by **Kendall and Gent Ltd.**, of Manchester (see Fig. 8). The exhibited model is intended for use with cemented carbide cutters and is provided with a 40-hp main drive motor, to enable it to take advantage of modern milling techniques. The base, table, column and head are very robust and rigid to withstand the heaviest cutting loads without distortion or vibration. The main motor is mounted on the head itself to ensure the shortest possible rigid and efficient transmission to the spindle. The spindle speed range is 15 to 840 rpm in eighteen steps. A simple interlocking system is incorporated to prevent the handwheels rotating at high speed on rapid traverse, and to prevent the engagement of power traverse when hand motion is in use. This is achieved by clutch operation of all handwheels and a lever mechanism which cuts off power to the table traverse motor when the clutch is engaged. The controls have been simplified and have been limited to two levers and a pendant push-button panel. Directional selection and starting and stopping are controlled from the pendant panel, which also has an emergency stop for cutting out all motors. The distance between centre of spindle and the column face is 3 ft and the maximum distance between the spindle nose and the table is 3 ft 5 in. The 9 ft by 2 ft 9 in. table has a longitudinal traverse of 7 ft 2 in. and a cross traverse of 3 ft 3 in. The maximum table feed is 18 in. per minute.

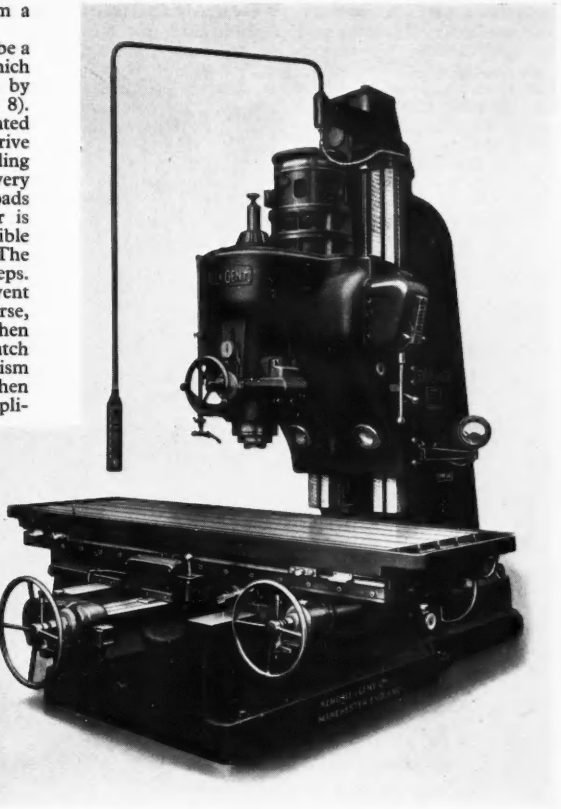

Fig. 8.

An important extension of their range of threading machines has recently been made by **Maiden & Co. Ltd.** of Hyde. Their machines now incorporate tangential die-heads, and the 2 in. model, see Fig. 9, is being exhibited. This new development has been achieved in co-operation with Gustav Wagner, Germany, the well-known manufacturers of die-heads, threading machines and cold sawing machines. The general construction of the machine remains the same as is used for the radial machines. It is strongly proportioned and has a 3-hp motor, driving through vee belts to a friction clutch. The saddle has a self-centering vice with hardened serrated grips. The die-head is capable of producing threads from ½ in. to 2 in. Whitworth and B.S.P., and its flanged body is bolted on to the machine spindle nose. The spindle bore is 2½ in. and it is possible to thread any length of work. This is achieved by releasing the grips at the end of the maximum saddle travel, moving the saddle backwards while the head is still rotating, and continuing threading after retightening the grips. The tangential chasers on this ingeniously designed head can be set accurately by means of a simple gauge and a dial gauge. The die-head speed range of 28 to 150 rpm covers the requirements of the work for which the machine is designed. The tangential heads can now be fitted to a wide range of Maiden threading machines up to the 6 in. size.

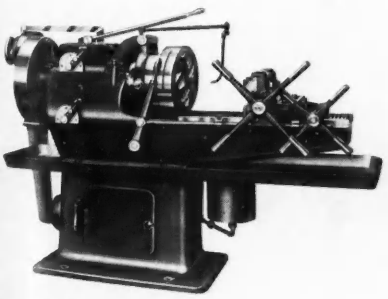

Fig. 9.

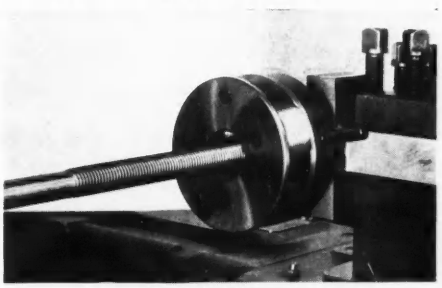

Fig. 10.

A recently developed attachment for producing threads by rolling on many commonly used machine tools is shown by **Machine Shop Equipment Ltd.** (Fig. 10). It is the Fette Self-opening Thread Rolling Head, which is available in a range of sizes for producing

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*Manufactured by Societé Nouvelle Cuttat, France.* (*E. Chagniard design*)

| | |
|---|---|
| Longitudinal Table Travel | - - 110″ |
| Transverse Travel of Column | - - 20″ |
| Vertical Travel of Spindle | - - 32″ |
| Spindle to Table (max.) | - - - 30″ |
| 15 Spindle Speeds | 5 — 1,250 R.P.M. |

24 automatic feeds in all directions, $\frac{1}{4}$″ to 55″ per minute.

Spindle Nose bored No. 50 Taper.

Spindle Motor of 30 H.P.

Full automatic cycles.

Table fully supported on bed througout its travel.

Automatic backlash eliminator for climb-milling.

Machine shown is Type E.1316. Larger and smaller types are available, both horizontal and vertical models, with single or duplex heads.

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threads from $\frac{1}{16}$ in. to $1\frac{1}{2}$ in. diameter. It is produced in two types, i.e., the stationary type for use on automatics, turret, capstan and centre lathes, and the rotating type for centre lathes, drilling machines and tapping machines. In both cases only the normal machine drive is utilised, and once the material has been brought to the head, self-feeding takes place. The accuracy of the produced thread, therefore, does not depend on leadscrews or gears. Adjustable stops are provided in the self-opening mechanism so that when the required length of thread has been produced, the thread rolls automatically open, release the threaded part and the head can be returned to the starting position. The heads utilise three precision-ground and hardened thread rolls, except in the case of the smallest size where only two rolls are used. The lead on the rolls is limited to $1\frac{1}{2}$ to $1\frac{3}{4}$ of the thread pitch, so that threads can be produced up to a shoulder to a distance less than the two thread pitches normally required. The actual deformation of the material takes place in the axial direction, resulting in smooth grain flow and well finished threads. It is claimed that the threads produced by this method are stronger than cut threads and that they have a smooth and abrasion-resistant, burnished finish. Very high rolling speeds can be used and correspondingly high production rates can be obtained. The power required for producing threads by this method is said to be considerably lower than that required for producing similar threads by cutting. The standard thread rolls supplied with the heads are suitable for non-ferrous metals and steels up to approximately 60 tsi tensile strength. Special rolls, capable of dealing with up to about 88 tsi steels, can be supplied. It is essential, however, that the rolled material should have an elongation of at least 5 per cent so that the deformation can take place without rupture. The rolls are claimed to have a very long life as the wear that takes place is almost negligible, even over very long production runs.

Broaching machines of improved design are being exhibited by the **Lapointe Machine Tool Company Ltd.** One of the machines shown is the Vertical Internal Pull-down type, known as model V.3 illustrated in Fig. 11. It has a pulling capacity of 15 tons, a maximum stroke of 42 in. and is intended for use with broaches having a length up to 48 in. The machine is now exceptionally heavily constructed and the heavier slides have no longer bearing surfaces. The main motor operating the hydraulic unit is rated at 30 hp and the hydraulic reservoir is designed to be completely sealed from dirt and impurities in the atmosphere. The main controls are on the front of the machine and consist of push-buttons for actuating hydraulic valves; auxiliary controls are provided on the side of the machine for use when setting up. The cutting speeds are steplessly variable up to 21 fpm and the rapid return speed is 42 fpm. Broach lifting is carried out by an automatic mechanism so that the broaches need not be handled during the cycle. The components to be broached are held in heavy platens, which reciprocate to and from the operating positions. Loading and unloading is thus facilitated and can be carried out during the upward stroke of the broach. Interlocking of the electric and hydraulic controls ensures the correct sequence of operations. The component platen can accommodate up to three components and three broaches can be used simultaneously, depending on the size of the work and the output required. The machine actually exhibited will be operating on two components simultaneously. The overall height of the machine is 142 in., its weight being 23,000 lb.

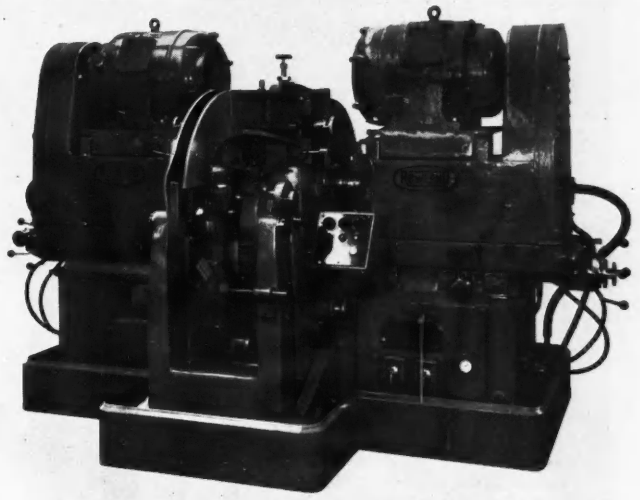


Fig. 12

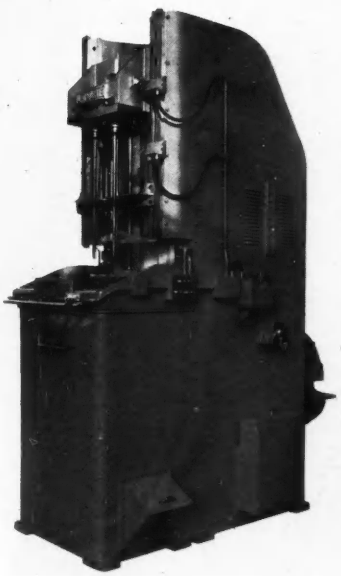
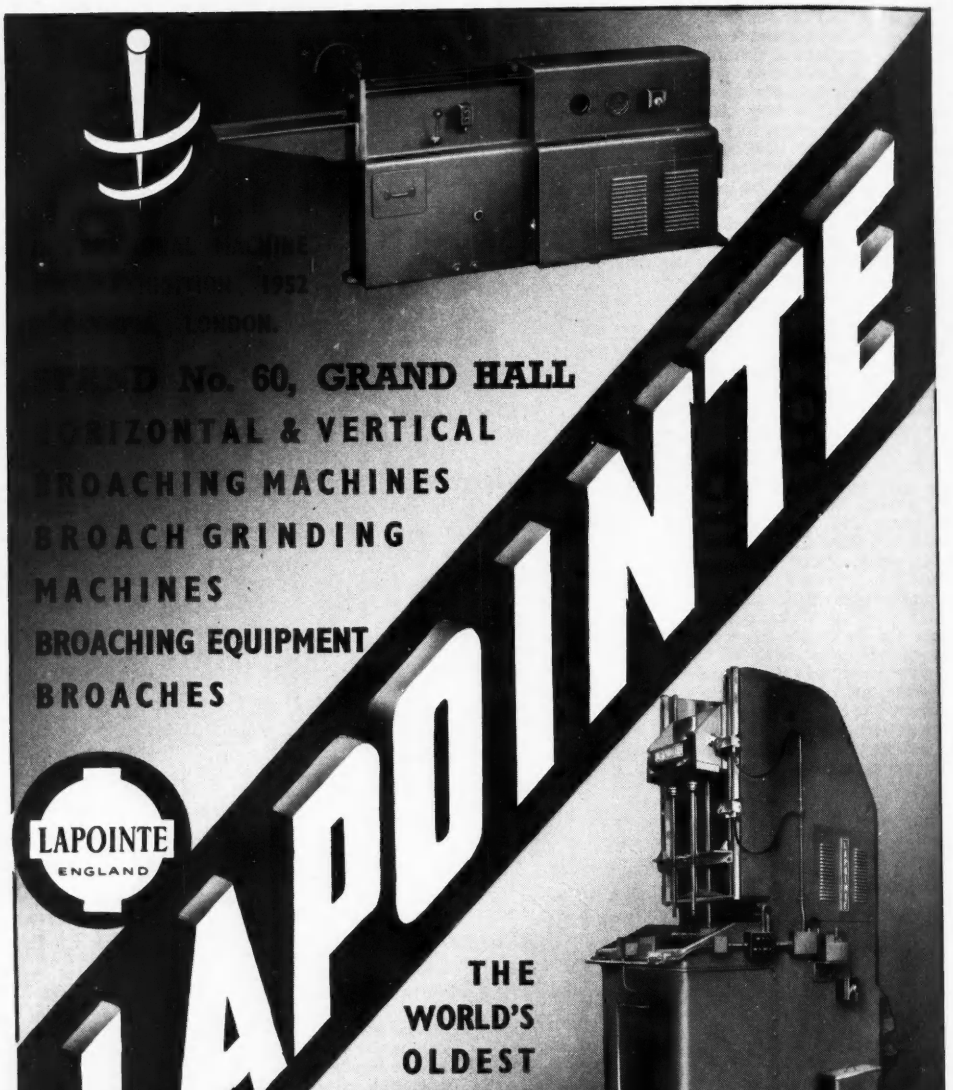


Fig. 11

Another interesting grinding machine to be shown is the 30 in. Duplex surface grinder, type "ADD/O," exhibited by the manufacturers, **F. E. Rowland & Co. Ltd.,** Stockport. This machine, shown in Fig. 12, has recently been redesigned and is intended for the grinding of components on two opposite sides simultaneously and at very high production rates. The two opposing wheelheads are mounted on slideways formed on the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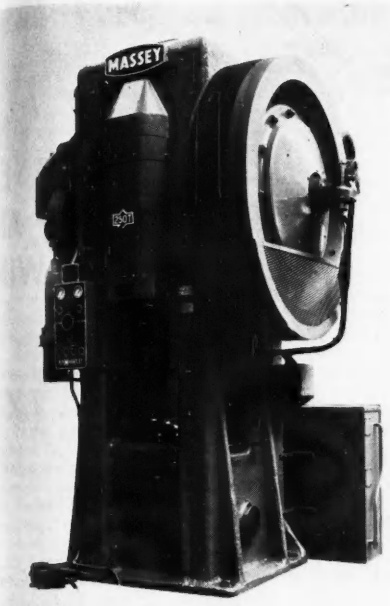


Fig. 13

upper face of the heavy body. Individual cycle or continuous operation is possible. In the former case, the hydraulic feed of the heads is started by a push-button, and the head movement is reversed automatically on reaching pre-set dead stops at the centre. The heads come to rest after returning to the starting position. On continuous operation, the heads travel repeatedly to and fro, their movement again being limited by dead stops for extreme inner and outer positions. Automatic signal light warning is given when wheels require replacement. This particular machine is designed for grinding both ends of coil springs or similar parts and incorporates power feed motion to the feed arms in which the components are held. The feed arm oscillates as the wheels are being fed towards the centre. On reaching the inner dead stop a dwell period commences, to ensure " sparking out." The feed arm can be modified to accommodate fixtures for various components.

**B. & S. Massey Ltd.,** of Manchester, have recently added to their range of mechanical forging presses. The new types are mainly intended for the production of drop forgings and also for the extrusion of parts such as automobile valves. In some instances, the machines can replace drop hammers, with a considerable increase in output. To suit conventional forging, and extrusion, the presses are made in two types: the high-speed type in sizes from 250 tons to 3000 tons, and the low-speed types from 250 tons to 1000 tons. All the presses, with the exception of the high-speed types above 1000 tons, are geared. The exhibit, Fig. 13, is the low-speed 250-ton model. All the machines, which are of very rigid construction with a cast steel frame, incorporate the " Massey " patent clutch. It is a multiple friction plate type, air-operated and air-cooled, and is mounted on the eccentric shaft. The main brake is mounted on the other end of this shaft and operates automatically in conjunction with the clutch, providing full control over all ram movements. Single or automatic strokes can be obtained, and " inching " upwards or downwards is also possible. A supplementary control is provided which enables two, three or four strokes to be obtained for one operation of the foot switch. This is particularly useful when preforming operations are involved. An extensometer for checking the press load during operation, and for checking die design, can be fitted.

A process frequently used in the U.S. aircraft industry for forming sheet parts is illustrated by the stretch-wrap forming machine Model A-10, Fig. 14, manufactured by **Hufford Machine Works, Inc.,** and marketed in this country by **Wickman Ltd.** The process uses dies having the contour of the component. The dies are firmly fixed, and the work, after being stretched almost to the yield point, is wrapped around the die, thus assuming its shape. After wrapping, the sheet is further stretched to exceed its elastic limit. The contour thus becomes set and permanent and simultaneously the yield point of the material is raised. It is claimed that the process possesses numerous advantages over other methods and parts can be produced which cannot be produced by any other method. The machine consists of a table for mounting the die, two pivoted arms with tension cylinders and jaws, and a crosshead with the arm-actuating cylinders. The arms are linked with the crosshead and swing simultaneously about their pivots up to a maximum arc of 90 degrees, thus providing the wrapping motion. The power required for the tension cylinders and arm-actuating cylinders, which have a pull of 35,000 lb. and 17,400 lb. respectively, is provided by a 15 hp motor driving two vane-type pumps. The distance between the clamping jaws is adjustable between 6 and 199 in. in 5 in. steps and the maximum width of sheet that can be formed is 10 in. The maximum die length for a 180 deg. bend at full tonnage is 68 in. All the hydraulic

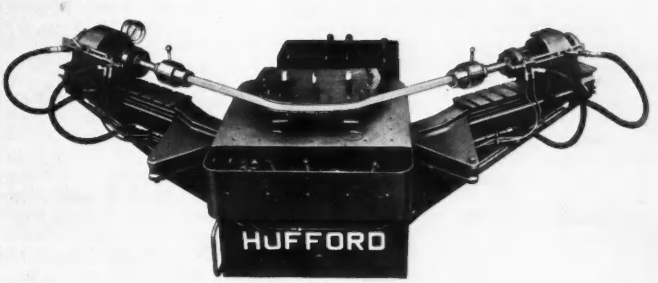


Fig. 14

controls are centralised on the front of the machine and include valves for selecting the direction for tension cylinders, setting the wrapping pressure and final stretching pressure, and controlling the direction of arm movement and its speed rate. The maximum swivelling speed for the arms is 10 seconds for a 90 deg. movement.

*To be continued.*

# Stanley Howard

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- **S.A.B.C.A., 1470 Chaussee de Haecht, Haren-Bruxelles, Belgium.** Universal Milling Machines.

# 2nd European Machine Tool Exhibition—Hanover, 1952

*An impressive array of machine tools and associated equipment from several countries in Western Europe will be exhibited in Hanover this year. The list of exhibitors includes many well-known names. In some cases the constructor's trade mark has become, in the course of years, if not generations, a generic name for its type of machine or process. In the presence of so much that is excellent, our business in these columns is not the buyer's choice, but the engineer's impression. The great bulk of the machine tool market will always be reserved for machines of a conventional type, in which one design differs from another in small, though important, details, not immediately apparent to the onlooker. In this preview we are biased in favour of the technically interesting and novel. Our main task is to point out the claims of those manufacturers who have something new to say which appears valid in the light of modern needs and trends. If judgment is involved it is a raw judgment, and by our silence we do not mean to belittle the merit of those designs which have resisted change because of their original quality.*

The two main trends in modern mechanical design are an increase in speed in every kind of machinery, and refinements in the utilisation of material. Both ultimately lead to greater emphasis on the fatigue properties of materials and components. No single measure is more effective in improving these properties than ensuring greater uniformity of the physical state of the surface in machined components. In many production schedules, sampling either has been, or ought to be, replaced by routine inspection of every component. Physical inspection as an operation in the production sequence needs improved methods and equipment. The firm of **Karl Frank Gmbh** of Weinheim-Birkenau, Germany, offers a whole range of material testing machines, both of their own design and manufactured under licence from Albert Schaefer & Co., Breisgau, Germany.

The machines to be exhibited this year are intended for the shop floor rather than the laboratory, and the emphasis seems to be on hardness testing. The hardness test is increasingly recognised as the most suitable for the workshop of all physical testing methods, even where it furnishes mainly indirect information. A new hardness testing machine (No. 510) is offered under the trade name "Hydromatik." The machine is hydraulically actuated and semi-automatic. This means that the component is placed and removed by hand, whilst the actual test is performed automatically, except for the readings which require the attention of the operator. In a further development, the testing machine No. 530, is capable of fully automatic testing. This machine can be supplied in three combinations:

(a) As standard equipment actuated by an electric motor. The placing and removal of the components is carried out by hand. The testing process takes place automatically upon starting by push-button.

(b) As before, but provided with an automatic sorting installation with separate rejection of too soft and too hard components.

(c) As a fully automatic mass production hardness tester, with an automatic loading installation fed from a magazine, and an automatic sorting installation which includes the automatic removal of the component from the machine.

The fully automatic electrically driven, mechanically actuated machine No. 530 is mainly intended for Rockwell hardness tests, but the semi-automatic hydraulically actuated machine No. 510 is equally suited for Vickers and Brinell hardness tests. All the same, only the Rockwell test is appropriate for real high-speed work, because it measures depth of penetration, which can be done by a dial indicator and does not require the optical aids for measuring the area of the indentation characteristic of the two other hardness test methods.

The design of the testing machines is therefore mainly governed by the conditions necessary to ensure that the Rockwell method should give accurate and reproducible results. These conditions are stated as follows:

(1) The support must be raised and brought against the stop by mechanical means.

(2) The dial indicator must be adjusted to zero automatically before indentation starts.

(3) The diamond must be allowed to penetrate under full load into the component only after the latter has been brought up hard against the stop.

All these design considerations are fully taken into account in the semi-automatic and automatic hardness testers.

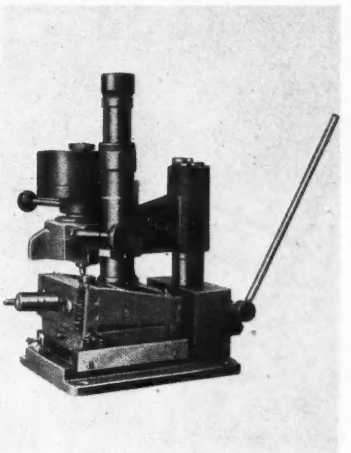

Fig. 1

Another exhibit embodies a new principle of a hardness test for shop inspection of the real uniformity of case-hardened components. A series of tests carried out in conjunction with a motor manufacturer has emphasised the clear distinction between the depth of the case and the depth of the hardened zone. It has been proved that hardness penetration is the decisive criterion which determines the performance of the component in operation. The most purposeful method for finding the hardness penetration is that of measuring the length of the narrow part of a scratch made along the surface of a section through the casehardened component. The scratch is performed by a diamond loaded with a constant force of between 2 and 6 lb. The width of the scratch under constant load clearly distinguishes between the core and the hardened case. This method has now been embodied in the scratch tester No. 549 (Fig. 1), developed by Dr. Quadflieg of the NSU Works.

Machine tools for the toolroom engaged in the making of dies increasingly occupy the attention of machine tool designers. In this branch the firm **Nassovia** will exhibit a number of machines manufactured under licence from the designers of the well-known Thiel machines, and also a range of original designs. The former group includes the sawing and filing machines both of the endless band and of the reciprocating types. The latter group comprises milling machines of the die-sinking type with copying equipment.

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The reciprocating filing and sawing machine, Nassovia-Thiel 1.14, Fig. 2, has been completely re-designed and now embodies the following advantages compared with earlier machines. Both the speed (strokes per minute) and the length of the stroke are infinitely variable by means of handwheels whilst the machine is in operation. Alteration of the stroke does not necessitate, as it did in the older machines, a displacement of the table. In the new machine the table is fixed in its height but can be tilted when necessary. Furthermore, in the new machines the return stroke is about three times faster than the working stroke, which results in a time saving of 17 per cent.

The makers claim special advantages for their fully automatic copying milling machines Nassovia VA 11-2n or VA 11-2s. Both machines can perform the milling of two identical dies simultaneously. Truly vertical surfaces can be reproduced and even sharp edges copied with great accuracy ($\pm$ 0·0004 in.). At the same time a good smooth surface can be obtained.

An interesting idea is embodied in the copying equipment. Whereas in most copying heads the tracer is guided solely by the position of its point on the surface to be copied, in the new type of equipment the tracer is continuously moving in circles, and thereby senses the direction of the tangent to the surface. Based on this fundamental idea, the hydraulically actuated, electronically controlled copying equipment enables a much better accuracy and improved surface to be achieved in the copying operation. The milling heads, with two milling spindles, can be chosen in the standard range of spindle speeds (150 to 2,900 rpm) or in the high-speed range (3,000 to 18,000 rpm) both capable of stepless variation. The high-speed spindles are of the well-known "Fortuna" type, and require a frequency changer. Solid carbide milling cutters of about $\frac{1}{4}$ in. diameter have been developed for this purpose.

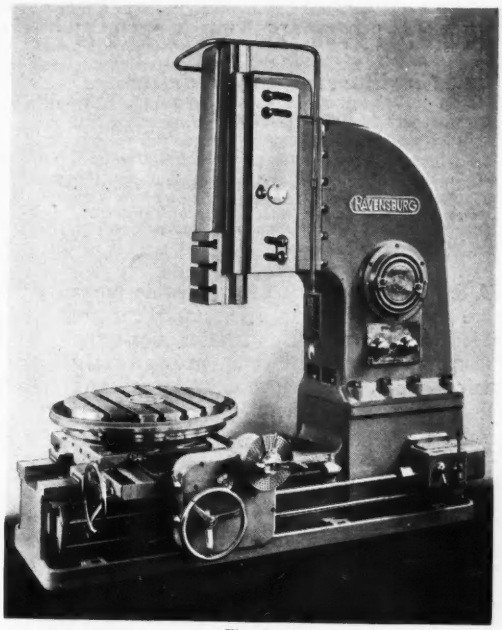


Fig. 3

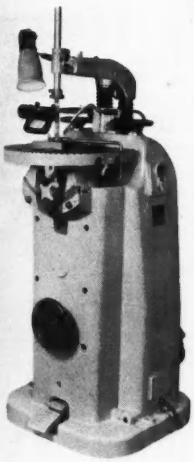

Fig. 2

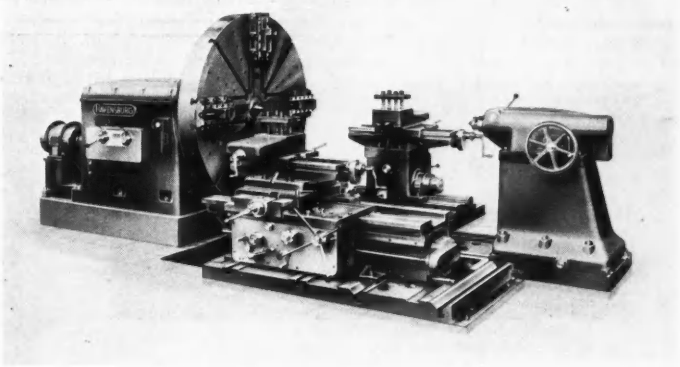

Fig. 4

The exhibits of **Maschinenfabrik Ravensburg AG.** will show a number of interesting solutions to the driving problem, mainly by all-electrical means. In the large slotting machine SL 750, shown in Fig. 3, with a maximum stroke of 2 ft 6 in., the tool carriage is driven by the d.c. motor of a Ward-Leonard set through a rack and pinion mechanism. By the use of a semi-saturated choke a good uniformity of motor speed and a fast change of excitation for the return stroke is achieved. This arrangement affords very short reversing times, an important consideration in slotting machines. This installation separately allows infinite variation of the cutting and the return speeds by means of two push-buttons. The adjustment of length of stroke and of the relative position of stroke and table is carried out by means of stops on an oscillating disc.

Another machine embodying an interesting electrical installation exhibited by the same company is the large surfacing lathe, Fig. 4, swinging 44 in. The spindle drive has 18 basic speeds selected by gear shift, but also includes an electric circuit to maintain a constant cutting speed in the facing operation. The field of the d.c. shunt motor is controlled by a small variable transformer, built into the tool support, which excites the field via a dry rectifier in a single-phase bridge circuit. The range of speed variation is three to one. When the required variation exceeds this range another basic speed has to be selected.

The lathe is provided with an automatic feed transmitted through a so-called "electrical shaft." This patented device consists of a pair of 2-kW commercial induction motors with slip-ring rotors. Two phases of the motors connected in series are fed by a.c. and the

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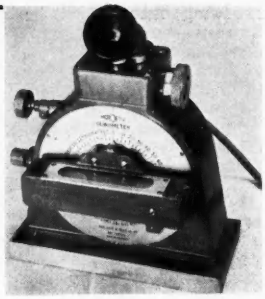
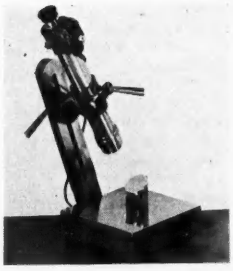
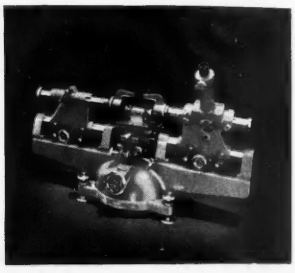
*Illustrated on right:*
*Top left. Microptic Precision Clinometer (reading to 10 secs).*
*Top Right. T 500 Universal Projector*
*Bottom Left. Angle Dekkor (reads direct to single minutes).*
*Bottom Right. Horizontal Measuring Machine (reads to 0.00005").*







A few examples from the very wide range are shown here. In addition, there are block levels, angular and linear measuring instruments, line standards, measuring microscopes, autocollimators and measuring and gauging projectors.

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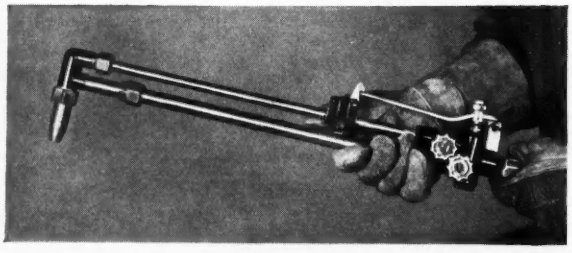

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third phase by d.c. The transmitting motor is driven mechanically by the face plate, and the receiving motor drives the tool carriage in complete synchronism. The "stiffness" of the electrical shaft is such that even accurate threads can be cut with this form of transmission.

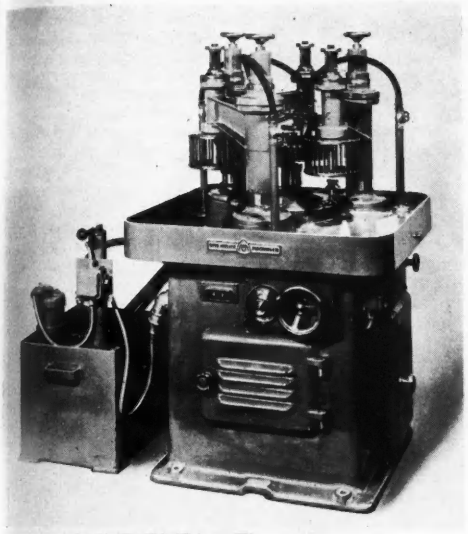


Fig. 5

Among the exhibits of the firm **Otto Müller,** Plochingen/Neckar, the tooth root lapping machine (Fig. 5) will be of particular interest. The great importance of the removal of all tool marks from the root radii of gear teeth is recognised by all authorities concerned with the fatigue strength of gears. The machine, known under the type number ZL 400, was developed in co-operation with **Hahn & Kolb** of Stuttgart, and is claimed to overcome the faults of earlier machines. The machine operates on the following principle.

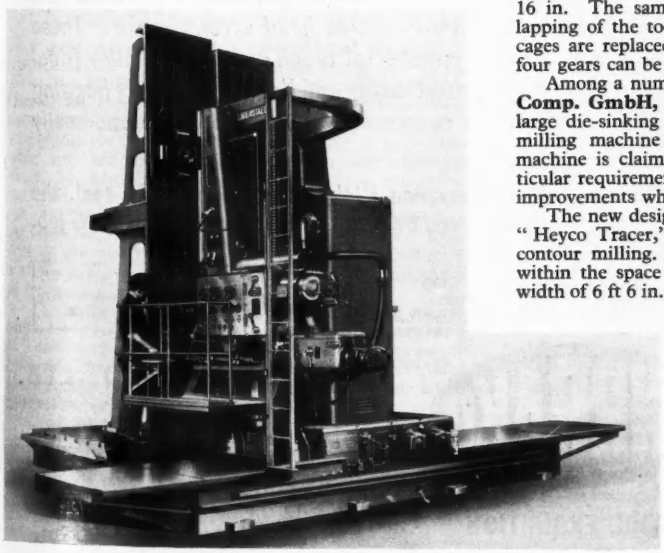


Fig. 6

The gear wheel to be treated is clamped on a vertical work-spindle, by which it is given a revolving and, simultaneously, reciprocating motion, whilst three lapping wheels are pressed into engagement with the gear wheel under spring load. The lapping wheels carry cylindrical lapping pins around their circumference, and have the appearance of circular cages. The pins are fixed and, in the process of wearing down, do not alter their original radius. As a result of the rotational and reciprocating motion, the relative direction of sliding between the pin and the tooth root has a component at

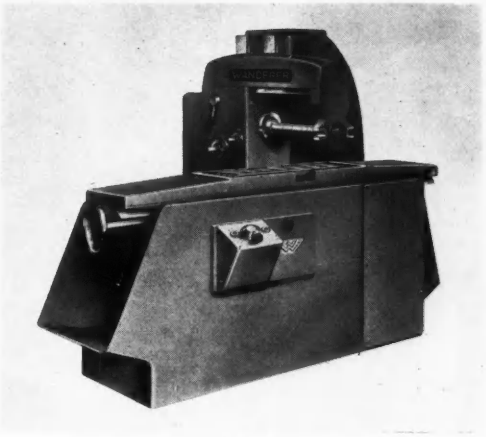


Fig. 7

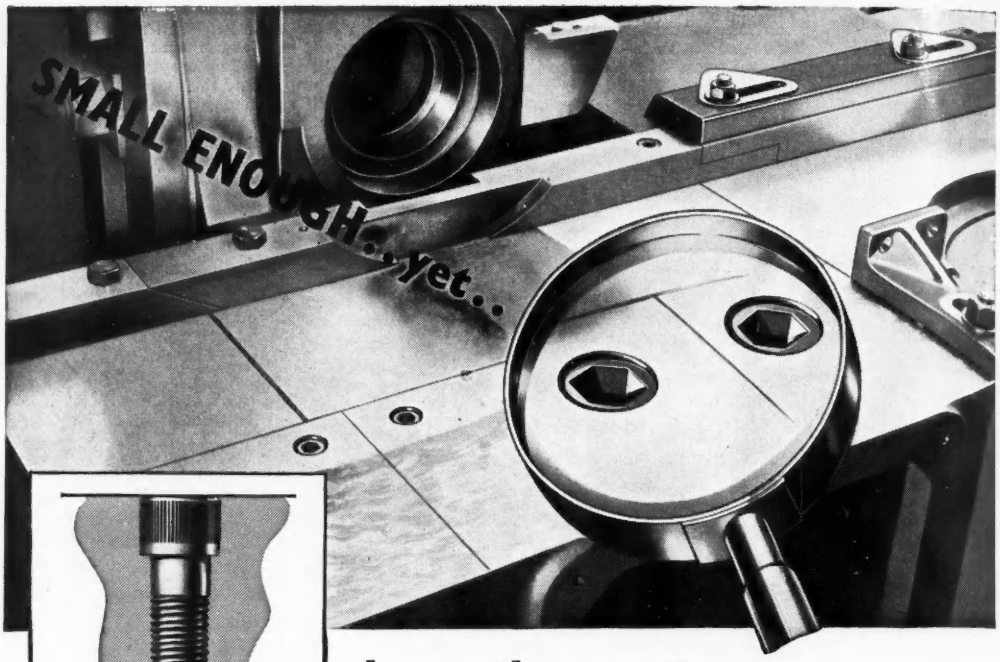
right angles to the gear axis, which has been found essential to eliminate the tool marks originating in the gear cutting operation. The lapping compound is fed between the lapping wheels and the gear wheel.

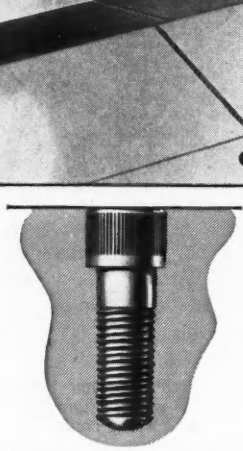
The work-spindle is driven by a motor through a PIV infinitely variable speed unit at speeds between 15 and 75 rpm. The reciprocating motion is performed by a crank mechanism, which permits the adjustment of the stroke between 0 and $\frac{5}{16}$ in. The maximum diameter of gears which can be treated on this machine is 16 in. The same machine can also be used for the lapping of the tooth flanks, for which purpose the pin cages are replaced by other gear wheels. In this way four gears can be lapped simultaneously.

Among a number of exhibits at **Heyligenstaedt & Comp. GmbH,** Giessen, the most unique will be the large die-sinking machine (Fig. 6), which is a copying milling machine with electrical tracer control. This machine is claimed to have been adapted to the particular requirements of car body builders by a series of improvements which appear this year for the first time.

The new design of the copying device, known as the "Heyco Tracer," permits both three-dimensional and contour milling. The machine is capable of copying within the space defined by a length of 16 ft 6 in., a width of 6 ft 6 in., and a depth of 32 in. It incorporates rapid traverses of up to 13 fpm in all three dimensions. A novel overload device can be adjusted to a pre-selected cutting depth. If the machine is overloaded, the rate of feed will be reduced until the tool is cutting freely.

The programme of **Wanderer-Werke AG** of Haar, near Munich, includes this year a new manufacturing type horizontal milling machine, distinguished not only by some novel design features but also by a distinctly new look,



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and will be shown under the name of "Autoplan," see Fig. 7. It is easily seen that the machine is destined for high-speed milling with carbide-tipped cutters, and much attention has been paid to stiffness and elimination of interference from swarf. The machine is part of a unit system of assemblies and can be supplied with different combinations of tool spindles and work tables. Another distinguishing feature is that the control of the automatic cycle, common to all modern horizontal milling machines, is performed by a separate rod mounted in the machine bed which carries all the required cams. This arrangement not only protects the cam surfaces but also allows interchangeable control set-ups which can be stored and returned when necessary.

Few firms in any industry can equal the record of **Hermann Pfauter,** now at Ludwigsburg, in having created a conception which, in the last fifty years, has changed only in detail. Gradual development has been observed throughout the years, and new designs have appeared since the war. This year a new spline-shaft hobbing machine will be exhibited for the manufacture of large spline-shafts. Among its novel details is the introduction of worm drive into the cutter spindle as well as the work spindle transmission. As in other new Pfauter machines, the combination of plunge feed and longitudinal feed is provided in this machine.

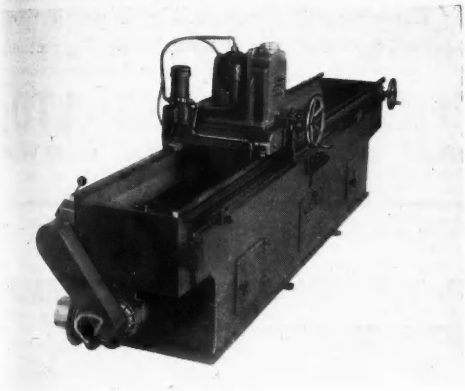

Fig. 8

A range of surface grinding machines particularly adapted for the grinding of knives and scrapers will be shown by **Gustav Gockel,** Maschinenfabrik GmbH, Darmstadt. In these machines the work-table is mounted within the bed of the machine to ensure greater rigidity. The guides for the grinding carriage are above the work-table and are therefore protected from the grinding swarf. The grinding carriage does not slide on vee-ways, but runs on rolls mounted on needle bearings which roll on the bedways. These ways are protected by steel bands and wear is almost eliminated. It is pointed out that the machine, which is shown in Fig. 8 is also suitable for the grinding of industrial ceramics and of synthetic resin materials.

The range of mechanical and physical testing equipment associated with the name of **Losenhausenwerk** of Dusseldorf is represented this year by a number of balancing machines of well-known design, but includes also two new items. Current emphasis on fatigue lends interest to the fatigue testing machine for alternating longitudinal tension, specially adapted for tests under elevated temperatures. This equipment is shown in Fig. 9. A new design of impact testing machine can be adapted for tests of either Izod or Charpy specimens (Fig. 10). These machines have been designed with due regard to the necessity for providing a constant impact velocity. The impact energy is imparted, as usual, by a pendulum, but the variation of this energy is

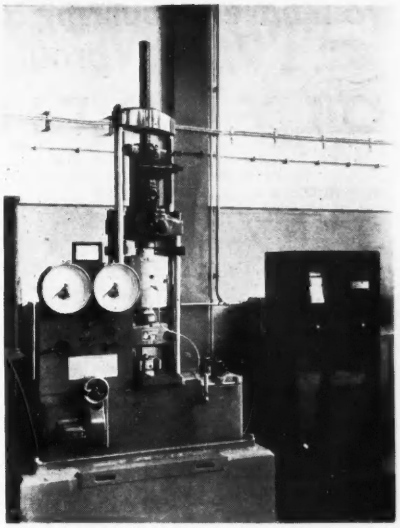

Fig. 9

Fig. 10

ensured by a change in the mass of the pendulum weight and a constant angle of lift is maintained whatever the material or size of the specimen. This method also has the advantage of giving an amplitude reading over the full length of the scale in all tests.

The **Société Genevoise** will show a large jig boring and milling machine, "Hydroptic-6," which, compared with its forerunner, Hydroptic-B, is of much sturdier design and therefore enables production milling and boring operations to be performed. The makers claim that quite heavy work can be carried out with the precision usually required from jig borers, and scales are provided which ensure an adjustment to $\pm 0{\cdot}0001$ in. Another interesting item on the stand will be the FPL 1000 machine for carrying out precise divisions in a straight line and machining such components as cards for textile machines.

*(To be continued)*

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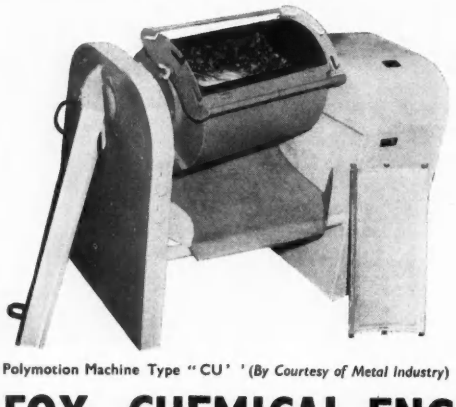

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# NEWS OF THE MONTH

## PERSONAL

**Mr. G. W. Alexander, B.Sc., M.I.E.E., A.M.I.Min.E.,** and **Mr. A. T. Purse, LL.B., F.C.I.S.,** have been appointed directors of Powell Duffryn Technical Services Ltd., 19 Berkeley Street, London, W.1.

**Mr. H. Bishop, C.B.E., B.Sc.(Eng.), F.C.G.I., M.I.E.E., M.I.Mech.E.,** has been appointed director of technical services of the British Broadcasting Corporation, in succession to **Sir Noel Ashbridge, B.Sc., M.I.C.E., M.I.E.E., F.K.C.,** who is retiring **Mr. R. T. B. Wynn, C.B.E., M.A., M.I.E.E.,** has been appointed chief engineer, and **Mr. F. C. McLean, M.B.E., B.Sc., M.I.E.E.,** deputy chief engineer.

**Mr. H. H. Burton, C.B.E.,** has been elected vice-president of the governing council of the British Iron and Steel Research Association, in succession to **Sir Alfred Egerton, F.R.S.,** who has resigned.

**Mr. F. B. Cawley, M.Met.,** has been appointed steelworks superintendent of the Workington Iron & Steel Co. Ltd., in succession to **Mr. L. R. E. Jenkins,** who retired after 41 years of service with the Company.

**Mr. Ivor Richard Cox, D.S.O., B.Sc., M.I.MechE., A.M.I.C.E.,** managing director of Metropolitan-Vickers Electrical Co. Ltd., Trafford Park, Manchester 17, has received the degree of Doctor of Science *honoris causa* from the University of Wales in recognition of his services to the electrical industry.

**Mr. R. C. Cross,** formerly foundry manager and chief metallurgist of David Brown-Jackson Ltd., has taken up a new appointment with Foundry Services Ltd., Long Acre, Nechells, Birmingham 7, in connection with future developments of the company in South Africa.

**Sir Bernard Docker, K.B.E.,** chairman of the Birmingham Small Arms Co. Ltd., has been appointed, in addition, managing director of the Company. **Mr. L. Chapman,** managing director of William Jessop & Sons Ltd., has been elected a director of the Birmingham Small Arms Co. Ltd.

**Mr. G. H. Foot, B.Sc.(Eng.), A.C.G.I., A.M.I.E.E.,** has joined the Equipment Division of Mullard Ltd., in charge of the telephone product group.

**Mr. David Fuller, B.Sc.,** of Belgrave House, Esh, Durham, has been appointed to the Colonial Mining Service as Inspector of Mines in Malaya.

**Mr. W. E. Fuller** has been appointed information officer of the British Steel Founders' Association.

**Mr. T. Gammon, M.I.Mech.E.,** manager of the Weybridge works, and **Mr. W. D. Opher, M.I.Mech.E.,** works superintendent of the Crayford works, have been appointed directors of Vickers-Armstrongs Ltd.

**Mr. F. Graucob,** managing director of Nu-Swift Ltd., Elland, Yorkshire, has been elected chairman, in succession to **Mr. A. Harland** who has become president of the Company. **Mr. E. E. C. Cawood,** general manager, has been appointed technical director.

**Mr. E. D. Hart, M.A., A.Inst.P., A.M.I.E.E.,** has joined the Equipment Division of Mullard Ltd. as head of the technical department. He is responsible for market surveys, technical publications and other technical commercial activities. Prior to this position, Mr. Hart was with Marconi Instruments Ltd. and was well known as technical editor of "Marconi Instrumentation." He is also chairman of the recently formed Joint Advisory Committee on Radio Communication and Radar Measuring Instruments.

**Mr. B. Hawley** has been appointed a director of A. E. Walsh & Partners Ltd., 92 New Cavendish Street, London, W.1.

**Mr. F. R. Head, J.P.,** has been appointed manager of George Kent Ltd., Lea Works, Luton.

**Mr. E. Howard,** city lighting engineer, Nottingham, has been elected President of the Association of Public Lighting Engineers, 22 Surrey Street, London, W.C.2.

**Mr. P. V. Hunter, C.B.E., M.I.E.E.,** is relinquishing, at his own request, his position as a deputy chairman of British Insulated Callender's Cables Ltd. At the request of the Company, he will continue to serve as a non-executive director, and will remain on the boards of several subsidiary companies.

**Dr. J. W. Jenkins, B.Sc. (Lond.), A.R.I.C., F.I.M.,** head of the development and research department of Tube Investments Ltd., has been appointed to the Council of the British Iron and Steel Research Association. He was nominated by the Iron and Steel Institute.

**Mr. A. Robert Jenkins, J.P., A.I.Mech.E.,** deputy managing director of Robert Jenkins & Co. Ltd., Rotherham, was installed as President of the Institute of Welding at the annual general meeting of the Institute on 22 July at the Institution of Civil Engineers. The new Vice-President of the Institute is **Mr. H. B. Fergusson, M.I.N.A., M.I.Mech E., M.E.I.Canada,** who for fifteen years has been a director of G. A. Harvey & Co. (London) Ltd.

**Mr. F. D. Langley, A.M.I.Mech.E.,** has been appointed manager of the newly formed Petroleum Industry Division of the Brush ABOE Group of Companies, 32 Duke Street, London, S.W.1.

**Mr. R. V. Maglione, M.I.E.E.,** of 11 Argyle Road, Southport, has been appointed electrical engineer in Tanganyika.

**Mr. K. C. T. Marshall** has been appointed director of Light-alloys Ltd., St. Leonards Road, London, N.W.10.

**Mr. William E. Miller, M.A.(Cantab.), M.Brit.I.R.E.,** has been unanimously nominated President-elect of the British Institution of Radio Engineers.

**Mr. J. Cecil Mitcheson, B.Sc.(Birm.),** has been elected President of the Institution of Mining Engineers, 436 Salisbury House, Finsbury Circus, London, E.C.2.

**Mr. Donald Eugene Murray, B.E., B.Sc.,** of 67 Upper Dromcondra Road, Dublin, has been appointed to the Colonial Engineering Service in Kenya.

**Mr. C. B. Nixon,** chairman and governing director of Leyland Motors Ltd., Leyland, Lancashire, has been appointed a member of the North West Electricity Consultative Council by the Minister of Fuel and Power.

**Mr. A. G. H. Pritchett** has been appointed general sales manager of Chamberlain Industries Ltd., Leyton, London, E.10.

**Mr. G. B. Proctor, B.Sc.Tech., A.M.I.E.E.,** has been appointed managing director of Transformers and Welders Ltd., Watford.

**Mr. Ian Quigley, B.Sc., A.M.I.E.E.,** has been appointed sales manager (Export) for the Lamps and Lighting Department of The British Thomson-Houston Co. Ltd., Crown House, Aldwych, London, W.C.2.

**Mr. R. R. C. Rankin, O.B.E., A.M.I.E.,** has been appointed technical manager of the New Equipment Division of Mullard Ltd. He also holds the corresponding position in Mullard Equipment Ltd.

**Mr. N. R. Reaney** and **Mr. P. C. Drabble** have been appointed to the Board of Geo. Salter & Co. Ltd., West Bromwich.

**Mr. T. G. Rodger,** formerly commercial manager of the Whitehead Iron & Steel Co. Ltd., has been appointed general manager of H. L. Reynolds Ltd., Old Leeds Steel Works, Balm Road, Leeds 10.

**Mr. John Ryan, C.B.E., M.C.,** vice-chairman of the Metal Box Co. Ltd., has been elected chairman of the British Standards Institution, to succeed **Sir Roger Duncalfe,** who had completed his three years term of office. **Sir Roger Duncalfe,** who is chair-


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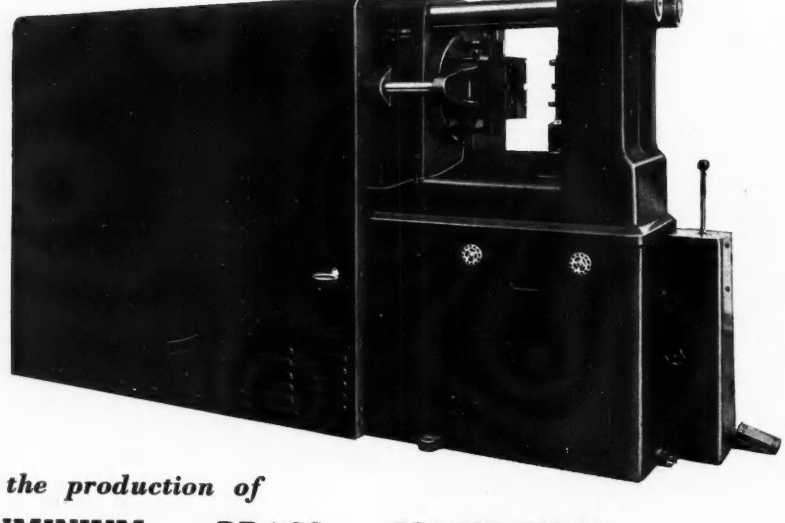

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man of **British Glues and Chemicals Ltd.**, chairman and Past President and now Vice-President of the Association of British Chemical Manufacturers, and Vice-President of the Federation of British Industries, has been elected Vice-President.

**Mr. R. H. Senior** and **Mr. A. R. Hughes** have been elected directors of the Cunard Steamship Co. Ltd., and of Cunard White Star Ltd.

**Mr. Eric Shaw,** sales director of the Oughtibridge Silica Firebrick Co. Ltd. and director of Monolithic Dolomite Ltd., Steetley, has been elected a member of the Council of the Refractories Association of Great Britain.

**Mr. H. F. Spencer** and **Mr. E. Julian Pode** have been appointed directors of RTSC Home Sales Ltd., 47 Park Street, London, W.1. This company has been formed by Richard Thomas and Baldwins Ltd. and The Steel Company of Wales Ltd., for selling flat rolled steel products manufactured by the two steel firms in all parts of the United Kingdom and Northern Ireland.

**Mr. Frank Turton, B.Sc.,** of Clifton Road, Worthing, Sussex, has been appointed chief broadcasting engineer in British Honduras.

**Mr. W. M. Widgery, F.R.Ae.S.,** has been appointed technical director, and **Mr. N. H. Payne, B.Sc., M.I.Mech.E.,** chief engineer, of Normalair Ltd.

**Mr. D. L. Hollis Williams, B.Sc., F.R.Ae.S.,** has been appointed technical director of Westland Aircraft Ltd., in succession to **Mr. Arthur Davenport, F.R.Ae.S.,** who has relinquished that office, but is retaining his seat on the Board.

**Mr. Douglas Wilson,** publicity manager of the United Steel Companies Ltd., Sheffield, has been elected chairman of the Council of British Manufacturers of Petroleum Equipment.

**Mr. H. T. Wordsworth** has retired from the position of general manager of Sanderson Brothers & Newbould Ltd., Sheffield, but retains his seat on the Board. **Mr. J. R. A. Bull,** formerly sales director, has been appointed managing director of the Company.

## BUSINESS NOTES

**Sunvic Controls Ltd.,** 10 Essex Street, London, W.C.2, have opened a Continental office at Skindergade 38, Copenhagen K., Denmark. Mr. B. Hveissel is in charge of this Continental office as European manager.

The title of the **Chesterfield Technical College** has been changed to Chesterfield College of Technology. The telephone number has been changed to Chesterfield 3481-2.

**The 6th National Convention of the Italian Metallurgic Association** will take place in Genoa from September 20 to 23. Mr. John Chipman, President of the American Society for Metals, will read a paper in French. He will also be presented with the Luigi Losana gold medal for his outstanding achievements in the field of science and metallurgy.

**Wild-Barfield Electric Furnaces Ltd.** have opened an office in Scotland in conjunction with G.W.B. Electric Furnaces Ltd. at 131 West Regent Street, Glasgow, C.2. Tel. No. Douglas 8839. The office will be under the control of Mr. D. McDermott.

The London Sales Office and the Railway Signalling Department of **Nife Batteries,** Redditch, Worcs., have just been transferred from their old address at 50 Grosvenor Gardens, S.W.1, to new premises at 53 Victoria Street, S.W.1.

**Houdry Process Corporation** and their foreign representatives, World Commerce Corporation, New York, announce that Albatros S.A. Belge pour le Raffinage de Petrole will install a Houdriflow catalytic cracking unit at their Antwerp, Belgium, refinery. This moving-bed installation, employing a gas-lift for catalyst circulation, is designed for a nominal capacity of 3,600 barrels per day. It will be the 85th Houdry licensed catalytic unit.

The agreements just concluded for the expansion and modernization of the Antwerp refinery also call for a feed preparation unit, a gas recovery and stabilization unit, a plant for the polymerization of light olefins produced in Houdriflow cracking operations, and new facilities for treating straight-run and catalytic gasolines.

Petrocarbon Ltd., Manchester, England, are consultants to Albatros S.A. The mechanical engineering, drafting and procurement are being handled by Head Wrightson Processes Ltd., of London, working in conjunction with Houdry Process Corporation.

**Contactor Switchgear Ltd.,** Wolverhampton, have on order for both home and export a large variety of standard and special automatic contactor type motor control gear. The range covers control boards for power stations, auxiliaries, water works, cement works, sewage works, rolling mills, steel mills, chemical plants and gas works.

The order book includes equipments for machine tools, electric furnaces, resistance welders, automatic tube draw benches, compressors, pumps, fans and material handling plant.

Special "built in" and "built on" control gear have been developed for the Machine Tool Industry, this includes equipment for Herbert Capstan lathes, Turret lathes, and vertical milling machines, Drummond automatic multi-tool lathes, Asquith radial drillers, Churchill grinding machines, and planing machines.

A comprehensive range of accessories such as push buttons, limit switches, float switches, joy-stick and master controllers have been developed.

Control boards and desks have recently been completed for the finishing, slitting and coiling lines at the Abbey Works, Glamorgan of the Steel Company of Wales.

The business carried on hitherto by two companies, Bryce Fuel Injection Ltd. and Berger Equipment Ltd., has been amalgamated and will be operated in future by **Bryce Berger Ltd.,** Ironbarks Works, Staines, Middlesex.

The directors of Bryce Berger Limited are: **Miles Beevor** (Chairman), **I. T. Morrow** (Deputy Chairman), **S. Webster** (Managing), **J. E. Markes** (Sales) and **W. A. Green.**

**Nife Batteries Ltd.,** Redditch, have introduced a new nylon safety vent which ensures that all alkaline caplamps can now be operated in a completely dry external condition.

Vent leakage was found to be due to one or more of four different causes—spraying during charging, the pressure ejection of liquid through the vent while the lamp is in service, over topping-up and badly fitting seating washers. Internal gas pressure during charging is responsible for the first two, the human element for the third and the repeated removal of vents before topping-up for the fourth.

The new nylon safety vent eliminates all these faults and has replaced the original type of steel vent.

The London Sales Office of **Britannia Batteries Ltd.** has been transferred from its old address at 66 Victoria Street, S.W.1 to new premises at 53 Victoria Street, S.W.1. Tel. No. Abbey 6168-9.

**The International Tin Research and Development Council** has resolved that it will in future be known as The International Tin Research Council. This change will not affect the policy of the Council nor alter its current activities.

**Elcontrol Ltd.** have moved into larger premises at Wilbury Way, Hitchin. Sales offices remain at 10 Wyndham Place, London, W.1. Tel. No. Ambassador 2671.

**Lunzer Rotating Centres.** In order to satisfy the demand for these tools and to ensure adequate stocks throughout the country, Austin & Lang (Sales) Ltd., Wembley, Middx., have appointed A. A. Jones & Shipman Ltd., Narborough Road South, Leicester, the Sole Distributing Agents in Great Britain and Overseas.

**National Service R.N.V.R. Engineering and Electrical Officers** serving in the Royal Navy can now apply for permanent commissions in the Royal Navy under the "University Candidate" scheme of entry. The Fleet Order announcing this explains that applications can be made after completion of one year's service.

Conditions of entry will be identical with those applying to University candidates who are not doing their National Service, except that certain time served as temporary officers will be counted for seniority purposes.

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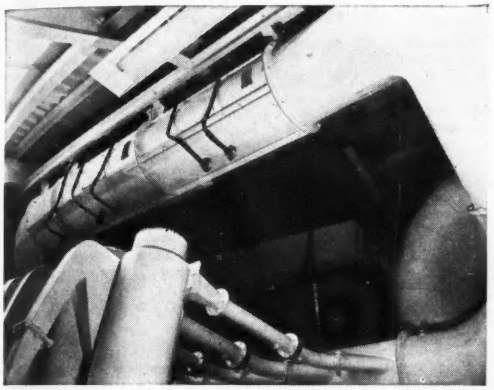
## DEVELOPMENT IN FLOUR MILL CONVEYING.

The problems of using axial flow fans for flour mill pneumatic conveying systems have now been overcome by Henry Simon Ltd. Hitherto, the accepted practice has been to employ centrifugal fans because, although it has been realised that greatly improved efficiency could be obtained with axial flow units, the high air pressures required for the conveyance of mill stocks would have necessitated the use of special and costly designs.

Moreover, these pressures would have entailed very high speed impellers having objectionably high sound levels. Another problem was that the motors generally available were unsuitable, since axial flow fans handling heavily dust-laden air need flameproof machines of suitable size and shape to meet the aerodynamic requirements of the fan.



**Aerofoil five-stage contra-rotating fan in pneumatic conveying system at the Westminster Mill of Hovis Ltd.**

Research work with high pressure contra-rotating Aerofoil fans was carried out in Henry Simon's experimental mill at Cheadle Heath, Stockport, which culminated in the installation of them at the Hovis Mill, Westminster. The substitution of multi-stage Aerofoils for centrifugal fans has substantially reduced power consumption and effected a new degree of flexibility of operation and a saving in space.

The capacity of the Westminster mill is 33 sacks an hour (132 tons a day). The pneumatic conveying system has 75 lifts and is divided into three separate sections in order to obtain the greatest economy in power consumption. Each of these sections has its own five-stage Aerofoil unit. The flexibility of the arrangement is illustrated by the fact that one five-stage fan has been divided into two parts; two stages of the fan are situated on one side of a 90° bend and the remaining three-stages on the other. With each fan the fifth stage is used for boosting the pressure during the starting-up period or during power cuts; normally this stage is switched off and idled with a consequent saving in running cost. The three multi-stage fan units can scarcely be heard above the background sound level of the mill. Together they consume 38 hp, whereas centrifugal fans doing the same work would have absorbed about 59 hp. This represents a saving of 35.6 per cent in power consumption.

The basic advantage of the contra-rotating Aerofoil fan comprises two impellers with opposite blade forms in a single cylindrical casing, one being driven clockwise and the other anti-clockwise by independent motors. This arrangement turns to advantage the air rotation which normally causes loss of pressure.

The second or downstream impeller receives the rotating air discharge from the first impeller, and as it is running in the opposite direction the relative velocity of the air over its blades is substantially increased.

The impellers are driven by Buxton-tested flameproof squirrel-cage motors developed by Woods of Colchester Ltd. specifically for Aerofoil fans. All the motors are identical and interchangeable. Furthermore, with a separate drive for each impeller the risk of a complete fan shut down is reduced to a minimum since a motor failure means only the temporary loss of one stage, the motor for which can be quickly replaced.

Since fan pressure varies as the square of the air velocity over its blades, the pressure developed by a contra-rotating fan is relatively high. In fact, a unit of this type produces about three times the pressure of a single-stage non-guide-vane fan, or more than twice that of a downstream guide-vane fan unit, and without a proportionate increase in noise. A static pressure of 7 in. w.g. can be obtained with one standard contra-rotating fan having a tip speed of only 14,000 ft. per minute.

An important feature of this design is that pressures can be easily stepped up by multi-staging with standard units. Two or more contra-rotating fans can be bolted end to end to form a multi-stage unit producing a pressure equal to the sum of the individual fan pressures. This is possible because the air enters and leaves a contra-rotating unit on an axial path, rotation occurring only between the two impellers. To quote an example, two 19 in. diameter contra-rotating units, each developing 7 in w.g., when bolted together in series form a four-stage fan developing a pressure of 14 in. w.g. Three such units bolted together form a six-stage fan developing 21 in w.g.

This simple form of multi-staging is particularly useful in flour mills. Apart from enabling high pressures to be obtained economically with standardised assemblies, it permits flexibility in the capacity of pneumatic conveying systems. Thus the capacity of a plant can be increased by simply adding another contra-rotating unit.

Furthermore, a simple but efficient form of regulation is inherent in the system. The volume handled by a two-stage contra-rotating fan can be reduced to about two-thirds of maximum, and the power input to about 40 per cent by switching off and idling the first stage impeller. With units of more than two stages the regulation obtainable is quite exceptional.

Thus by running a four-stage unit with different motor combinations, it is possible to regulate volume down to 50 per cent in five well-graduated steps as follows :—

| | |
|---|---|
| 100% volume .. .. .. | 100% power input |
| 85% ,, .. .. .. | 66% ,, ,, |
| 75% ,, .. .. .. | 55% ,, ,, |
| 60% ,, .. .. .. | 33% ,, ,, |
| 50% ,, .. .. .. | 20% ,, ,, |

In the case of a six-stage fan, a substantially wider range of volume control can be arranged with as many as ten steps if so desired. Apart from the exceptional range of volume control which this new system provides, it is much more efficient than any form of regulation available hitherto. This is due partly to the low idling loss, but more especially to the fact that volume is reduced by switching motors off while the remaining motors continue to run on full load.

Another point which recommends the Aerofoil fan for mill systems is that being inserted directly into the run of ducting it can be installed neatly in confined spaces and without the bends which centrifugal fans necessitate. The general cleaning up of the layout which is thus effected reduces the system loss to a minimum.

One of the requirements in conveying flour and mill stocks is a fine surface finish to the fan blades and this is an inherent feature of the Aerofoil impeller, which is die-cast from silicon aluminium alloy in polished steel moulds. The efficiency of the Aerofoil fan is 30 per cent to 40 per cent higher than that of many of the centrifugal types hitherto employed for mill conveying. Their total efficiencies exceed 70 per cent over a wide range of duties; the peak efficiency is about 78 per cent, based on total pressures.

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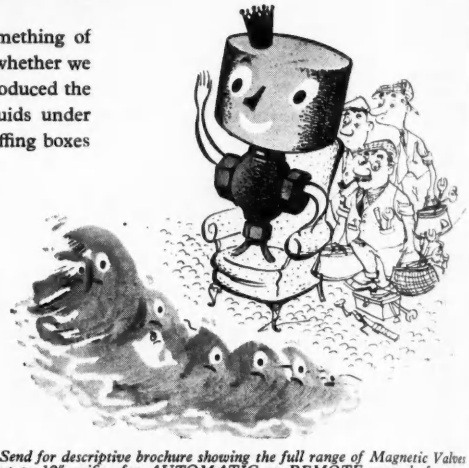

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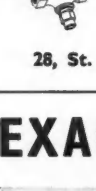

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## PRODUCTIVITY IN THE INTERNAL COMBUSTION ENGINE INDUSTRY

It is a little over two years since the report of the Internal Combustion Engine Productivity Team was published and something over two and a half years since its visit to the United States. The industry has in that time assimilated what the team had to say and many companies have incorporated the recommendations of the report in policies of expansion.

Internal combustion engine production, especially production of diesel engines, has expanded since 1932 and markedly since the war; in fact some companies have expanded their output almost phenomenally in the post-war years. The team's visit came in the middle of this period of rapid expansion and, though it has been of material assistance to a large number of companies, the effect of the report was to add momentum to changes already taking place rather than to initiate new developments. The industry is now stabilising itself after its rapid expansion and fitting itself to meet increasing competition from Germany and other countries.

Comparative measurement of productivity has been found statistically difficult in most industries. In the internal combustion engine industry there is no unit to measure comparative output that is completely free from statistical objection. Value and quantity are often meaningless as measures of output; brake horsepower units, though sometimes misleading, are frequently taken as units of output for the industry. The main objection to brake horsepower as a measure of output is that a change in engine design could speed the engine up and increase its brake horsepower without any increase in physical output. Figures either of quantity or b.h.p. which are quoted below have been provided by the companies concerned and are quoted because, in spite of possible statistical objections, they do give an indication of the importance of the changes that have been made in recent years in the industry.

A number of companies report increases in both output and productivity during the last few years. British Polar Engines Ltd. has doubled production in the last five years with little increase in the labour force; Crossley Brothers Ltd. has trebled its output since 1947 with a comparatively small increase in personnel; Davey, Paxman & Co. Ltd. has in the last few years more than doubled its output of certain major engine components formerly made by specialist suppliers; Mirrlees, Bickerton & Day Ltd. has increased its output, measured in b.h.p., from 50,000 b.h.p. in 1946 to 210,000 b.h.p. in 1950 while total manpower was not quite doubled; the National Gas & Oil Engine Company has increased its output measured in b.h.p. from 60,000 b.h.p. in 1947 to 200,000 in 1951 with an increase in total manpower of nearly 60 per cent; F. Perkins Ltd. has increased its output measured in b.h.p. from 229,000 b.h.p. in 1946 to 2,125,000 b.h.p. in 1951; Petters Ltd. has expanded its output of cylinders from 800 a week in 1948 to 2,000 now without any equivalent increase in manpower; Ruston & Hornsby Ltd. with a small percentage increase in personnel has more than doubled its output since 1947.

Many companies in the industry are in the middle of reorganisation which is likely to increase their efficiency still further. With continued world-wide mechanisation of agriculture, with the expanded use of diesel locomotives and the increased use of diesel engines as power units, there seems every prospect of continued expansion in the size of the world market. The competitive power of the industry has been greatly strengthened in the course of the post-war years and this increased strength is likely to make it possible for the industry to ensure for itself a good share of the world market in coming years.

The productivity team can claim no more than to have been of assistance in the process of rationalisation in the industry. It pointed out some weaknesses that affected the whole industry, such as the inadequate supply of machine tools and the insufficient capacity in this country for forging and machining of solid-forged crank shafts; on both these matters the British Internal Combustion Engine Manufacturers' Association has done its best to improve matters by factual investigation and report and by discussions with Government departments and the associations of the other industries concerned.

The main value of the team's report lay in its critical analysis of the factors making for high productivity in individual American companies, thus augmenting what was already known as a result of private visits to America from this country. In general, simplification of the range of products is the basic characteristic of American industry making for high productivity. In the British internal combustion engine industry the ranges of engines produced in any one factory were already being limited by many companies long before the team's visit; and this policy continues.

For example, Blackstone & Co., Ltd. has reduced the number of horizontal types produced from 22 to 6 since 1936; Davey, Paxman & Co., Ltd. has cut down the number of models produced from 22 to 4 since 1948; the National Gas & Oil Engine Company has cut its range from 30 to 14 models of engine since the war; R. A. Lister & Co. Ltd. has in recent years limited its range to 3 main types of engine instead of 12 and one of its subsidiary companies is concentrating on one model only; Mirrlees, Bickerton & Day Ltd. is now concentrating on two main models which have been designed and brought into production since 1946; Petters Ltd. has since 1948 concentrated on two main models of both diesel and petrol engines; Ruston & Hornsby Ltd. plans to manufacture basically standard engines to which non-standard parts can be added as required; whereas some other companies, such as F. Perkins Ltd. and Stuart Turner Ltd. have always specialised within narrow limits.

Where the team's report may have had more specific influence is in encouraging the streamlining of production by reorganisation of factory lay-out and, often, production methods. All the more important companies in the industry have either concluded a process of reorganisation or are in the middle of it. The achievement of a flow-line of production is of course not unrelated to the simplification of the range of production; this is exemplified by R. A. Lister & Co. Ltd. which as well as limiting the range of engines produced has opened a number of new sub-factories each of which concentrates on one type of production. In this manner the company has reorganised its production to achieve a flow of work through each factory. F. Perkins Ltd. is extending and reorganising its factory with the aim of reducing work in progress to a minimum. Mirrlees, Bickerton & Day Ltd. has established machine lines for the machining of cam-shafts, cylinder liners and crank-shafts; the machined parts are sub-assembled and sub-assemblies are fed to the sides of the main assembly line. Davey, Paxman & Co. Ltd., in the process of rationalisation of its engine production, is changing over from small to large batch production and is specialising its processes of manufacture. British Polar Engines Ltd. like many other companies, has extensively re-equipped the machine-shops with new machine-tools. W. H. Allen, Sons & Co. Ltd. has undertaken a comprehensive scheme of machinery replacement since the war.

Assembly shops have, and are being, reorganised with the same object. Most companies making smaller and medium-sized engines are assembling them on conveyors. The National Gas & Oil Engine Company has developed a flow-line for the KB and PB engines for the production of which an assembly roller conveyor runs direct to the test shop; the fitters are supplied on one side of the conveyor from material feeding trays. Ruston & Horsnby Ltd. is in process of splitting up the assembly of the medium sized engines into stages on the assembly line; by the side of the main assembly line sub-assembly is carried out of parts, such as cylinder heads. At Petters Ltd. there are two main assembly lines, one for petrol and one for diesel engines.

In the attempt to achieve a flow-line of production greater attention has been paid to methods of handling. Apart from the extended use of conveyors and lift trucks, tilt racks on trolleys have been found valuable to move parts such as connecting rods around the shop. Davey, Paxman & Co. Ltd. uses radio intercommunication between the transport office, lift trucks, cranes and other vehicles; R. A. Lister & Co. Ltd. has paid special attention to the use of compressed air for jigs and lifting equipment; Mirrlees, Bickerton & Day Ltd. has installed a number of jib cranes along the assembly line; F. Perkins Ltd. has adopted palletised unit handling by fork lift trucks. The practice is spreading of having a specialist to look after handling problems.

A number of companies, like the Turner Manufacturing Company Ltd. have given more attention to methods of production planning and control.

The need for the extension of work study in the industry has been accepted by many managements and work-study is increasingly being adopted in the industry, but one or two companies have encountered difficulties with their rank and file employees when attempts have been made to introduce it.

Consideration has been widely given to payment under incentive bonus schemes in addition to piece-work payment which is the basic method in the industry.


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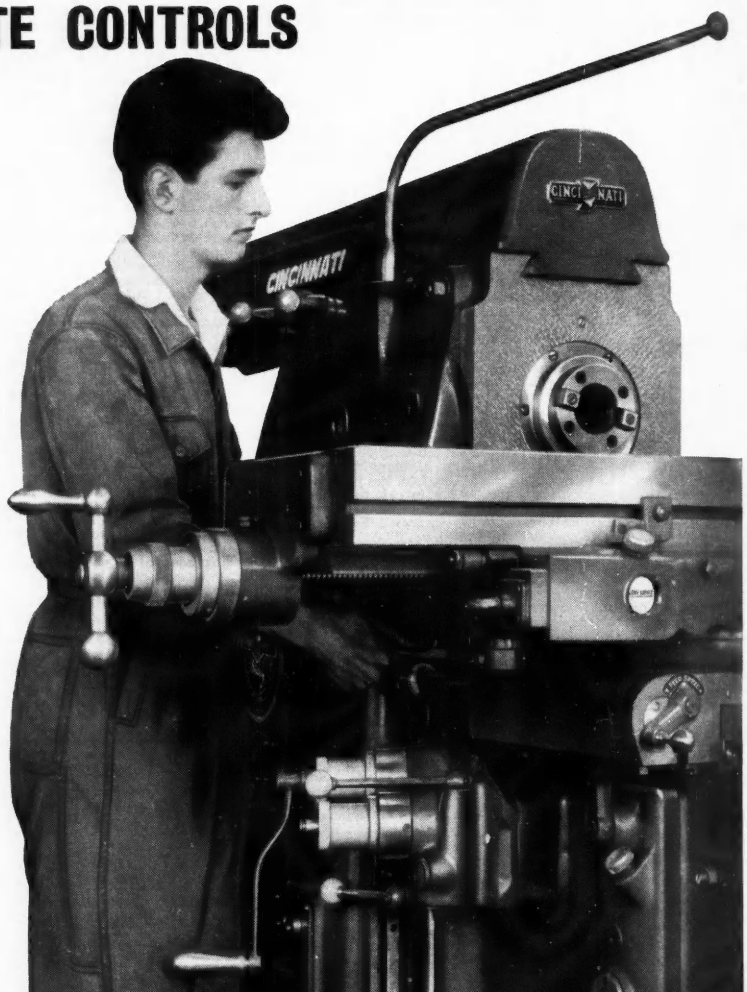


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## BOOKS

**The Fundamentals of Library Classification.** By Bernard I. Palmer and A. J. Wells. Publishers: George Allen & Unwin Ltd., Ruskin House, Museum Street, London, W.C.1. 114 pp. Price: 8/-.

This book is written with the object of finding out what classification achieves, where it fails, and what steps are needed to increase its value. It is, therefore, of particular interest to trained librarians for whose problems it is difficult to find fully satisfactory solutions within the present systems of classification.

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**The Engineer's Approach to the Economics of Production.** By John Reid Dick. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. 248 pp. Price: 21/-.

The author of this book, Mr. John Reid Dick, who was managing director of an engineering works and foundry, died last year. He left a book of exceptional merits and great topical value. He was a good engineer and an economist of considerable knowledge. His lucid explanation of the economic principles which must be applied to the work of design and production engineers in order to achieve "efficiency" or "productivity" is of utmost interest.

**Chemical and Electro-Plated-Finishes.** By H. Silman. With Foreword by H. Moore. Publishers: Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. 480 pp. 135 illustrations. Price: 50/-.

The rapid developments in metal protection and plating have necessitated a revised and substantially enlarged edition of this book, the first edition of which appeared in 1948.

The author is treating the subject in a comprehensive yet concise manner, always having in mind the practical needs of designers, manufacturers and users concerned with electro-plating and allied processes.

The book contains a wealth of useful information on all aspects of combating corrosion and it can be strongly recommended to engineers and metallurgists as well as to all concerned with metal plating and finishing processes.

**Modern Marine Engineering.** By D. W. Rudorff. Publishers: Temple Press Ltd., Bowling Green Lane, London, E.C.1. 154 pp. 23 diagrams and 12 plates. Price: 9/6.

**Steel Defects and their Detection.** By Henry Thompson. Publishers: Sir Isaac Pitman & Sons Ltd., Parker Street, Kingsway, London, W.C.2. 84 pp. 82 figs. Price: 15/-.

**Elementary Heat Power.** By Harry L. Solberg, Orville C. Cromer and Albert R. Spalding. Publishers: John Wiley & Sons, Inc., New York and Chapman & Hall Ltd., London. 624 pp. Price: 52/-.

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